TECHNICAL REPORT

TR-127

Dynamic Testing of Splitters and In-Line Filters with xDSL Transceivers

Issue: 1
Issue Date: May 2009

Issue History

Issue Number	Issue Date	Issue Editor	Changes
1	May 2009	Greg Gough, East by North	Original

Comments or questions about this Technical Report should be directed to:

Editor:	Greg Gough	East by North	greg.gough@zdsl.com
T&I WG Chair	Les Brown	Infineon	
Vice Chairs	Lincoln Lavoie	UNH-IOL	
	Massimo Sorbara	Conexant	

Table of Contents

List of Figures

List of Tables

Summary

This Technical Report enables high quality delivery of triple play services by maximizing the interoperability of splitters and in-line filters with xDSL transceivers in an active, dynamic, telephony environment including on-hook, off-hook, ringing, and ring trip events. This Technical Report relates to TR-100 (ADSL2/ADSL2plus Performance Test Plan).

1 Purpose and Scope

1.1 Purpose

This Technical Report was created in co-operation with ETSI Technical Committee ATTM-TM6. Compiling the xDSL Splitter requirements with relation to POTS signals and the delivery of IPTV services requires a more complex modeling of the actual POTS signals. This includes the dynamic behavior of the POTS signals, their power and the impedances via which the signals and their power are applied to the xDSL splitters.

1.2 Scope

The Technical Report contains first a study of the signals modeling the POTS disturbances into xDSL in Section 7. This is followed in Section 8 by interactive or so-called "interworking" tests of splitters with xTU transceivers.

This Technical Report will focus on dynamic testing only. It is assumed that these splitters have already been tested against relevant static splitter (e.g. ANSI/ATIS, ETSI, ITU-T and other Broadband Forum) requirements.

This Technical Report establishes a methodology for verification of a baseline performance of a system without splitters as device under test (DUT). Elements of this system are named baseline devices i.e. there are two xTU modem baseline devices and two splitter baseline devices. Once acceptable baseline performance is verified, then it is understood that for any Test Case defined in this Technical Report, the system is the configuration to be considered subject to the specified pass/fail criterion. The system includes, but is not limited to, a complete end-to-end setup using Central Office splitters and remote splitters or in-line filters, xTU modem baseline devices, POTS Central Office AC and DC terminations (including battery and ring-generator) and a telephone model.

Dynamic testing of a splitter is performed in a live POTS and xDSL modem environment. Performance of the system is measured by evaluating the Layer 1 primitives reported by the xTUs (CRCs, FECs, etc.) in steady state during on-hook and off-hook, and in the presence of transients, caused by cadenced ringing, and by off-hook or on-hook transitions of phones. Off-hook transitions include ring trip events, i.e. on-hook to off-hook transitions during ringing.

2 References and Terminology

2.1 Conventions

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

MUST This word, or the terms "REQUIRED" or "SHALL", means that the definition is an absolute requirement of the specification.

MUST NOT This phrase, or the phrase "SHALL NOT", means that the definition is an absolute prohibition of the specification.

SHOULD This word, or the adjective "RECOMMENDED", means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications must be understood and carefully weighed before choosing a different course.

SHOULD NOT This phrase, or the phrase "NOT RECOMMENDED" means that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.

MAY This word, or the adjective "OPTIONAL", means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

2.2 References

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

[1]	G.992.5	*Asymmetric Digital Subscriber Line (ADSL) transceivers – Extended bandwidth ADSL2 (ADSL2plus)*	ITU-T Recommendation	2005
[2]	G.993.2	*Very high speed Digital Subscriber Line transceivers 2*	ITU-T Recommendation	2006
[3]	G.992.3	*Asymmetric digital subscriber line transceivers 2 (ADSL2)*	ITU-T Recommendation	2005
[4]	G.997.1	*Physical layer management for digital subscriber line (DSL) transceivers*	ITU-T Recommendation	2006
[5]	O.9	*Measuring arrangements to assess the degree of unbalance about earth*	ITU-T Recommendation	1999
[6]	T1.421-2001	*In-Line Filter for Use with Voiceband Terminal Equipment*	ATIS Recommendation	2006

	(R2006)	*Operating on the Same Wire Pair with High Frequency (up to 12 MHz) Devices*		
[7]	ATIS-0600016	*Remote End POTS Splitter Requirements*	ATIS Recommendation	2008
[8]	ATIS-0600016	*Splitters Used for Line Splitting and Line Sharing Applications*	ATIS Recommendation	2003
[9]	ETSI TS 101 952	*Access network xDSL transmission filters; Part 1: ADSL splitters for European deployment; Sub-part 1: Generic specification of the low pass part of DSL over POTS splitters including dedicated annexes for specific xDSL variants*	ETSI Recommendation	2004

2.3 Definitions

The following terminology is used throughout this Technical Report.

A-wire and B-wire	wires in the 2-wire local loop connection provided from the exchange to the NTP (Network Termination Point).
active splitters	splitters that use active components for parts of the low pass. These splitters could require an external source of power. Note that the use of active components in the high pass part is unlikely.
central splitter	see master splitter.
cadence	see ringing cadence.
distributed filter	see in-line filter.
DUT	The DUT (device under test) is one splitter or one or more in-line filters.
far end echo	speech that is fed back to the talker in a telephony connection with a round trip delay (i.e. the delay between talking and hearing the feedback), of greater than 5 ms, resulting in a distinguishable echo.
feeding circuit	a model of the POTS central office equipment which merges DC and AC signals as presented in Section 7.1.1, Figure 7-1.
HSI splitter	a splitter that is primarily intended to deliver High Speed Internet (HSI) access to the xDSL user.
in-line filter	a low pass filter that is added in series with each of the parallel POTS TE. Each of these parallel connected filters (in the in-house cabling) is known as an in-line filter.
master splitter	term used to describe an installation with is a single splitter at the demarcation point where the POTS signal and the DSL signal are separated from each other. The master splitter can be active or passive and designed for either HSI or triple play performance.
microfilter	see in-line filter.
off-hook	state of the POTS equipment at either end of a loop connection when the NTP terminal equipment is in the steady loop state. NOTE: In the case where multiple TEs are present at the customer end of the loop, then the TE is considered to be off-hook from the perspective of testing the splitter when only one of the terminals is off-hook.
on-hook	state of the POTS equipment at either end of a POTS loop connection when the NTP terminal

	equipment is in the quiescent state. NOTE: In the case where multiple TEs are present at the customer end of the loop, then the TE is considered to be on-hook from the perspective of testing the splitter only when all of terminals are on-hook.
passive splitters	splitters containing exclusively passive components.
ringing cadence	the timeline for ringing and non-ringing (e.g. in North America a typical ringing cadence is 2 seconds of ringing followed by 4 seconds of non-ringing).
ringing signal	typically an AC signal injected on the POTS loop to alert the user of an incoming call using values in the range of 90 volts rms and 20 Hertz in North America with additional world ringing signals used in this Technical Report.
Triple Play	voice, data, video services provided with POTS for voice service, and xDSL for data and video services.
triple play splitter	splitters with the main purpose of delivering video services with minimal errors, when the xDSL is provisioned for interleaved latency.
voiceband	the POTS analog signals.
xDSL-friendly	Ringing is both injected and removed without any voltage step between a- and b-wire in the moment of transition.
xDSL-unfriendly	Ringing is both injected and removed with a random voltage step between a- and b-wire in the moment of transition.

2.4 Abbreviations

This Technical Report uses the following abbreviations:

AC	Alternating Current
ADSL2	Asymmetric Digital Subscriber Line version 2, revision by ITU
ADSL2plus	Extended Bandwidth ADSL2, revision by ITU, ADSL2 extended to 2.2 MHz
ANSI	American National Standards Institute
ATIS	Alliance for Telecommunications Industry Solutions
ATU-C	ADSL transceiver unit at the at the ONU (or central office, exchange, cabinet, etc., i.e., operator end of the loop).
ATU-R	ADSL transceiver units at the at the remote site (i.e., subscriber end of the loop).
AWG	American Wire Gauge
AWGN	Additive White Gaussian Noise
BER	Bit Error Ratio
BW	Bandwidth
CLIP	Calling Line Identification Presentation
CO	Central Office (Local Exchange)
C_{OH}	C off-hook (Capacitance)

CPE	Customer Premises Equipment (≡ Terminal Equipment)
CRC	Cyclic Redundancy Check
DC	Direct Current
DS	Downstream, i.e. CO to CPE side
DSLAM	DSL Access Module, i.e. equipment at the CO side with multiple xDSL transceivers
emf	Electro-Magnetic Force
EC	Echo Cancelled
FEC	Forward Error Correction
FDD	Frequency Division Duplexing
ETSI	European Telecommunications Standards Institute
HPF	High Pass Filter
HSI	High Speed Internet
IC	Integrated Circuit
IMD	Intermodulation Distortion
IPTV	Internet Protocol Television
IPv6	Internet Protocol Version 6
ISDN	Integrated Services Digital Network
ITU	International Telecommunication Union
LE	Local Exchange (Central Office)
LCAS	Line Card Access Switch
LCL	Longitudinal Conversion Loss
MTBE	Mean Time Between Errors
NTP	Network Termination Point
NDR	Net Data Rate
OH	Off-hook
POTS	Plain Old Telephone Service (used throughout instead of PSTN)
rms	Root Mean Square
PSTN	Public Switched Telephone Network (see POTS).
R_{feed}	DC Feeding Resistance as part of the Feeding Circuit
R_{OH1}	R1 off-hook
R_{OH2}	R2 off-hook
SLIC	Subscriber Line Interface Circuit
STP	Shielded Twisted Pair
SUT	System Under Test

TE	Terminal Equipment (e.g. Telephone, Fax, voiceband modem etc.)
THD	Total Harmonic Distortion
US	Upstream, , i.e. CPE to CO side
UTP	Unshielded Twisted Pair
VB	VoiceBand
V_{Bat}	DC Feeding Voltage (e.g. +/- 50 V_{DC}), part of the Feeding Circuit
V'_{Bat}	DC Feeding Voltage (e.g. +/- 50 V_{DC}), part of the Parallel Feeding Circuit
VDSL2	Very high speed Digital Subscriber Line version 2, revision by ITU
V_{ring}	Ringing Voltage V_{rms}
VoIP	Voice Over Internet Protocol
VTU-O	VDSL transceiver unit at the at the ONU (or central office, exchange, cabinet, etc., i.e., operator end of the loop).
VTU-R	VDSL transceiver units at the at the remote site (i.e., subscriber end of the loop).
xDSL	Digital Subscriber Line (either ADSL2plus or VDSL2)
xTU	Stands for either xTU-C or xTU-R
xTU-C	xDSL Transmission Unit Central, i.e. at the CO side of the line: ATU-C or VTU-O
xTU-R	xDSL Transmission Unit Remote, i.e. at the CPE side of the line: ATU-R or VTU-R
Z_{AC}	AC termination impedance
Z_{on}	N. American on-hook AC termination impedance
Z_{off}	N. American off-hook AC termination impedance
Z_R	AC European harmonized complex reference POTS impedance
Z_{ring}	Impedance modeling the load represented by a worst-case electronic ringer circuit
Z_{trip}	Impedance modeling of the load represented by electronic ringer circuits, the hook switch, and a single off-hook load

3 Technical Report Impact

3.1 Energy Efficiency

TR-127 has no impact on energy efficiency.

3.2 IPv6

TR-127 has no impact on IPv6 support and compatibility.

3.3 Security

TR-127 has no impact on security issues.

4 Introduction

This Technical Report will be used as a reference for the specifications of splitter equipment and testing. Existing xDSL splitter requirements and testing documents have been used as a source for this Technical Report.

There are several reasons driving the need to have a requirement for a series of splitter tests:

- Ringing and Ring Trip events have been shown to have an adverse effect on the quality of IPTV services.
- Higher data rates used with VDSL2 [2] affect the splitter differently than the lower bandwidth requirements of ADSL2plus [1].
- A need to analyze how splitters might affect the xDSL performance, in terms of achievable bitrate and margin

The requirements and test methods for xDSL over POTS splitters are defined for splitters installed at the network side of the local loop, either at the local exchange or at a remote cabinet, and at the user side near the NTP. In the case of splitters at the CPE side, the requirements and test methods for xDSL over POTS splitters will specify the master (also called central splitter) splitter as well as the in-line filters (also called distributed filters or microfilters). The master splitter is normally intended for use at the demarcation point of the customer premises.

The majority of the requirements and test methods for xDSL over POTS splitters, are generic and applicable to all xDSL over POTS splitters, including triple play splitters, splitters for high speed Internet access and in-line filters. Some operators also deploy VDSL2 with in-line filters.

4.1 Caution on the use of In-Line Filters

When deploying micro-filters for use in a “Distributed Filter Configuration” this Technical Report does not take into consideration the effects of the in-home wiring which can be short runs from the demarcation point to the CPE equipment that can act as bridged taps which can cause reflections and pick up noise. Therefore, the wiring can have detrimental effects on IPTV type applications with ADSL2plus and VDSL2, i.e. on the achievable bitrate, margin and robustness. Test results and performance numbers obtained using this Technical Report are done with the in-line filters wired in star configuration and a null or short cable length on each leg. The Performance of ADSL2plus and VDSL2 when deployed in the field with In-Line Filters could vary considerably from the performance numbers derived from tests in this Technical Report.

5 Test Tools and Calibration

5.1 Ring Generator and DC Battery Source

The purpose of the ring generator equipment is the creation and injection of POTS ringing transients into the exchange port of the CO splitter. These transient signals and their related voiceband impedances are defined by Section 7.3.1 of this Technical Report. The ring generator and DC battery source SHALL be capable of producing the ringing signals, either AC only or both AC and DC, as required to perform the tests described in this Technical Report, including, but not limited to, producing the appropriate ringing voltages and currents into the test loop.

Ring generators can introduce out of band signals, which adversely affect the xDSL transmission systems. These effects SHALL be characterized before any splitters are put under test as DUT. The procedure used to characterize the ring generator SHALL be documented along with the results.

5.1.1 Minimum Requirements for the Ring Generator

The Ring Generator SHALL have the capability of providing a stable source of ringing signals that are in accordance with the requirements for both North America and Europe.

These requirements are as follows:

[1] AC Ringing Voltage (no load)	90 to 105 Vrms
[2] Output Frequency Range	20 Hz, 25 Hz, 50 Hz
[3] Frequency Accuracy	±3%
[4] Current Source	≥5REN
[5] THD	Less than 5%
[6] Output resistance	< 850 Ohm
[7] Cadence	500 ms to 4 sec
[8] Ringing Injection	DSL Friendly, Zero Crossing
[9] Off-hook detect and Ringing removal	≤220 ms ± ½ ringing period

Note: Requirements 7 through 9 could be implemented by external circuitry if necessary

5.1.2 Minimum Requirements for the DC Battery Source

The DC Battery Source SHALL have the following minimum requirements:

Range	-34 to -70 VDC
Output ripple and noise	100 mVrms max
Voltage Drift	≤1.0% over a period of 8 hours

5.2 Test Loop realization

Line simulators or real cable setup can influence the test results for transient type tests which have strict voltage, current and linearity requirements.

To avoid noise enhancement as stated in the NOTE of Section 5.6, or the spurious coupling mentioned in Section 5.3, the line simulator or the real cable setup line models or line simulations SHALL achieve balance properties in the POTS band and the xDSL band, as follows:

$LCL \geq 43$ dB for $f \leq 1$ MHz

$LCL \geq [43 - 10 \times \log_{10}(f / 1\ \text{MHz})]$ dB for $f > 1$ MHz

The measurement of LCL SHALL be done according to ITU-T recommendation O.9. The requirement is in line with representative worst-case requirements of actual lines used in the field.

It is the responsibility of the party performing the testing to document and correctly characterize and select the line simulator or real cable to realize the test loops.

The cable type used to implement the test loop SHOULD be appropriate for the modem technology being used [e.g., ADSL2plus Annex A, using a 26AWG plastic cladding cable].

5.2.1 Test Loop Accuracy requirements for cable

Test loops MAY be realized by using real cable instead of simulators.

NOTE: When real cable is used instead of a line simulator, it will be difficult to find twisted pair cables with the characteristics of the ADSL loops of TR-100 or the planned VDSL loops. Also when using real cable it is permitted to use a cable with larger diameter, provided that it is longer to achieve an equivalent insertion loss as the reference loops at some characteristic frequency.

Therefore the cable-based loops realized with cable differing from the types specified in **Table 8-1** for use in tests according to this Technical Report SHALL have the following properties:

- The IL of the loops SHALL have in an insertion loss that is within 5% of the insertion loss in dB of the test loops of Table 8-1 at 300 kHz, or no worse than ±1 dB, whichever is tighter.
- The impedance of the cable loop SHALL converge above 200 kHz to a stable impedance with absolute value between 75 Ohm and 150 Ohm, but values in the range 100 to 135 Ohm are recommended.
- The use of a homogeneous loop is recommended, but this is not an absolute requirement.
- The test lab SHALL deliver the identification of the cable, including the characteristic impedance.
- The test lab SHALL deliver a plot of the insertion loss of the reference test loops and the actual cable-based realization used in the set-up from 30 Hz to the highest used xDSL frequency. 100 Ohm SHALL be used as reference impedance for this plot.

5.3 Cabling

Cabling, switches and other equipment are needed to connect the DSLAM, the loop simulator, the noise generator and the xTU-R. The wiring SHOULD be kept as short as practically possible in order to minimize the noise coupled into the cabling.

When wiring multiple in-line filters to the end of a line at the CPE side the wiring distance between the individual filters SHALL be less than 40 cm. See also the text on the “star configuration” in the note at the end of the introduction, Section 4.

Recommended cables are Cat5 UTP and STP. Since the length is typically short (e.g., 5 to 10 feet) this does not influence the measurements. STP is only required when there is high EMI in the vicinity (typically from engines, air conditioning units) or for longer cables coming from the DSLAM. If the test is performed in a large operational lab (where also other work is done), then consider this lab as a high-noise environment.

Connect the shield to the loop simulator ground only (one-sided grounding). A badly connected shield can even make the performance worse. In case of doubt, use unshielded twisted pair.

Computer screens and power supplies might radiate in the frequency bands used by VDSL2. These devices SHOULD be placed at a distance from the setup or even be switched off. Either internal or external power supplies might generate this noise. When the pickup noise levels are greater than -150 dBm/Hz, they will limit the VDSL2 performance and influence the test results.

The VTU-R and VTU-O and their wiring SHOULD be physically separated, since when testing on long loops, crosstalk might occur between the cabling of the CO side and the CPE side. This spurious coupling might bypass the loop and might inject CO noises into the CPE side (or vice versa) without the appropriate loop attenuation.

5.4 Loop Simulator

Loop simulator equipment MAY be used to emulate a real cable loop in the test environment. In order to fully implement the test cases described by this Technical Report, the loop simulator SHALL be capable of simulating the loop under test, while supporting the voltage and current requirements of these transient tests. The maximum expected DC voltage can be derived from Section 7.1.1. The maximum expected AC ringing voltage (RMS) is specified in Section 7.3.1.1, which can result in a peak voltage of about 1.6 times larger, assuming a distortion of the ideal sinusoidal waveform. The loop simulator SHALL support the sum of these signals. Of course, when these maximum values for certain countries are either larger or smaller, the maximal peak voltage will scale accordingly.

The maximum expected current on a phone line will exist, when the line is charged to the peak AC ringing voltage, summed with the maximal DC battery voltage (if present during ringing). If the off-hook phone model of Section 7.3.2.1 is connected to the line at the instant of the highest voltage, the largest possible current peak will exist temporarily while the line discharges into the resistances and other components modeling the phone. The effect of the xDSL signals on the line current can be ignored, because these high frequency signals represent little energy.

The behavior of Line Simulators might be affected by ringing current and DC voltage and current which might adversely affect the xDSL transmission systems. These effects SHALL be characterized before any splitters are put under test as DUT. The procedure used to characterize the ring generator SHALL be documented along with the results.

5.4.1 ADSL2plus specific accuracy requirements

The accuracy requirements for the loop simulator SHALL be in accordance with Section 3.1.1/TR-100.

5.4.2 VDSL2 specific accuracy requirements

The accuracy requirements for the loop simulator are For Further Study.

5.5 Noise Generator

The noise generator equipment used SHALL be capable of injecting an AWGN at -140dBm/Hz into both ends of the test loop. AWGN is injected to ensure the tests are reproducible between different test labs, and to ascertain that the tests are closer to the actual deployment, where the absence of noise is not a realistic scenario.

5.5.1 ADSL2plus specific

The ADSL2plus noise generator SHALL have an accuracy of +/- 1 dB over the range of 20 kHz to 2.208 MHz.

5.5.2 VDSL2 specific

The VDSL2 noise generator SHALL have an accuracy of +/- 1 dB over the range of 20 kHz to 30 MHz.

5.6 Feeding circuits

To inject stationary DC voltages and currents one SHALL use feeding circuits according to the equivalent circuit diagram of Figure 7-1 of Section 7.1.1, realized according to Figure 7-4 to Figure 7-7 of Section 7.3.1. Similarly, to inject transient DC and ringing AC voltages and currents feeding circuits according to Figure 7-4 to Figure 7-7 of Section 7.3.1 SHALL also be used.

The circuits for the injection of the DC voltage and current SHOULD be sufficiently balanced, such that common mode noises or propagation effects in the lab environment do not adversely affect the bitrates, margins and the CRC error counts. For this purpose the feeding circuits for the DC injection SHALL be balanced in the POTS band in line with the balance requirements of the POTS termination. The LCL of the DC feeding circuits SHALL be at least 46 dB in the voiceband between 300 Hz and 4 kHz. Above the POTS band the balance (LCL) SHALL be at least 30 dB up to highest used frequency of the xDSL system used in the tests.

NOTE: The implementation examples of feeding circuits with sufficient balance over a wide frequency range is given e.g. in the T1.421-2001 (ATIS). The necessary balance of the POTS circuits could be achieved by using transformers instead of individual coils, which due to matching problems might not be balanced sufficiently.

5.7 DSLAM and Modem Feature Tables

Table 5-1 and Table 5-2 SHALL be filled with the requested information before starting any tests in order to have all the information about the DSLAM and Modem that is being used to measure the performance of the Splitter or In-line filter and to have a reproducible test environment.

Table 5-1: DSLAM Feature Table

Test Item	Specification
DSLAM General Information	
Vendor information (product name and revision)	
Hardware Version	
Software Version	
Line Card Type, Version	
Line port used	
Industry Standards Supported	
Chipset (Vendor, HW and Firmware)	
xDSL Characteristics	
supported max rates - downstream	
supported max rates - upstream	
possible coding options	
Used duplex procedure (FDD, EC)	
frequency usage (bin allocation) downstream	
allowed usage Upstream bins (option below #33)	
Support of S = ½	
Support of framing modes	
Support of trellis	
Support of bit swap	
Support of fast path	
Support of interleaved path	
Dying Gasp detection	
Power Cut Back implemented? (yes/no)	
U0 used (VDSL2 only)? (yes/no)	

Table 5-2: CPE Feature Table

Test Item	Specification
CPE General Information	
vendor information (product name and revision)	
Industry Standards Supported	
HW version	
SW version	
serial number	
Modem form (interfaces)	
PCI/USB driver version	
Chipset (Vendor, HW and Firmware)	
xDSL Characteristics	
supported max rates - downstream	
supported max rates – upstream	
possible coding options	
used duplex procedure (FDD, EC)	
allowed frequency usage downstream	
used Upstream bins (option below #33)	

Test Item	Specification
Support of S = ½	
support of framing modes	
support of trellis	
Support of bit swap	
Support of fast path	
latency channel supported (fast, interleaved, max. interleave depth)	
Power Cut Back implemented? (yes/no)	
dying gasp (yes/no)	
U0 used (VDSL2 only)? (yes/no)	

5.8 Splitter and In-Line Filter Specifications

Table 5-3 through Table 5-6 SHALL be filled in with the requested information before starting any tests in order to have all the information for both the CO and the CPE ends of the SUT for the purposes of repeatability.

Table 5-3: CO Splitter Specifications

Test Item	Specification
CO Splitter General Information	
Manufacturer	
Product Name	
Splitter Type (ADSL2plus or VDSL2)	
Splitter Classification (HSI or Triple Play)	
Integrated with DSLAM or stand alone	
Card Version Number	
Design Version Number	
Chassis Version Number	
Connectors type on Chassis (e.g. RJ-21)	
Secondary Protection Yes/No	
Serial Number	

Table 5-4: CPE Master Splitter Specifications

Test Item	Specification
CPE Master Splitter General Information	
Manufacturer	
Product Name	
Splitter Type (ADSL2plus or VDSL2)	
Splitter Classification (HSI or Triple Play)	
Splitter Version Number	
Design Version Number	
Secondary Protection Yes/No	
Serial Number	

Table 5-5: In-Line Filter Specifications

Test Item	Specification
In-Line General Information	
Manufacturer	
Product Name	
In-Line Filter Classification (ADSL2plus or VDSL2)	
Filter Version Number	
Design Version Number	
Secondary Protection Yes/No	
Serial Number	

5.9 Test System Variables

Table 5-6 SHALL be filled in with the system variables that are used in tests 8.2 to 8.10 for the purposes of repeatability. **Values outside of these ranges SHALL NOT be considered for Pass/Fail criteria according to this Technical Report.**

Table 5-6: Test System Variables

Parameter	Valid Range	Actual
Real Cable	Not Used , 26AWG or 0.4 mm or equivalent	
Line Simulator	Not Used , Report make and model	
V_{Bat}	34-70 V	
Ringing Frequency	20-50 Hz	
Ringing Injection Model	one of Figures 7-4, 7-5, 7-6, 7-7	
Cadenced Ringing (including acceleration of the cadence)	T_{RING}: 500ms – 4s $T_{Silence}$: 500ms – 4s	
Ring Trip Cadence (including acceleration of the cadence)	Tring_start_delay: ≥ 200ms Ton_hook: 500ms – 1s Toff_hook: ≥ 500ms Toff_hook_detect: ≤ 220ms ± ½ ringing period	
Steady State DC current On-hook	0 – 10 µA	
Steady State DC current Off-hook	13 mA to 80 mA	

6 General functional description of xDSL over POTS, including splitters and POTS signals

The main purpose of the xDSL over POTS splitter is to separate or combine the transmission of POTS signals and xDSL signals, enabling the simultaneous transmission of both services on the same twisted pair. The splitter also serves to protect POTS from interference due to egress (and ingress) from xDSL signals. Equally it protects the xDSL transmission from transients generated primarily during POTS signaling (dialing, ringing, ring trip, etc.), and also prevents interference to the xDSL service due to fluctuations in impedance and linearity that occur when telephones change operational state (e.g. from off-hook to on-hook). Insertion of a splitter or in-line filter in existing POTS lines will have a low impact on the performance of the POTS service.

6.1 Functional diagram (Informative)

The functional diagram for the combination of splitters and xDSL combination is given in Figure 6-1 and Figure 6-2.

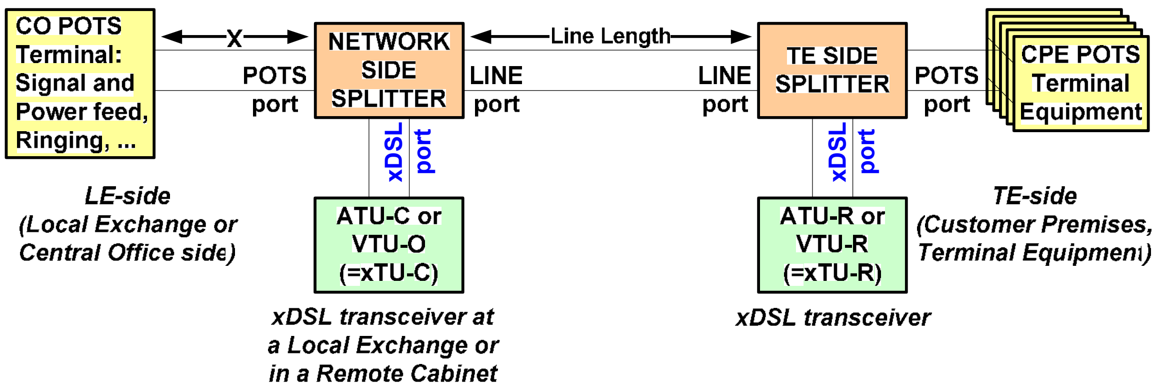


Figure 6-1: Functional diagram of the xDSL master splitter configuration

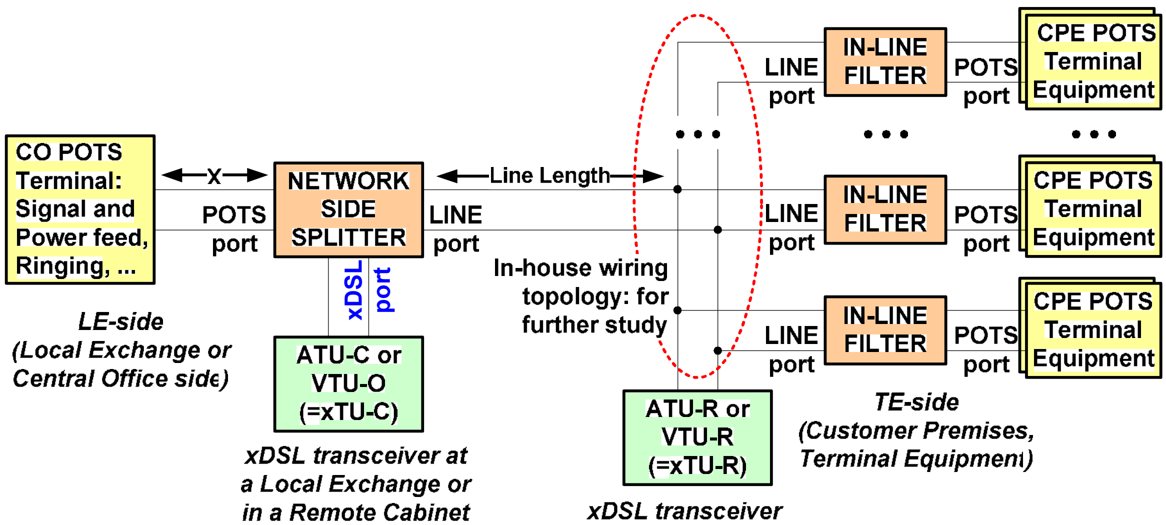


Figure 6-2: Functional diagram of the xDSL in-line filter configuration

NOTE: For a Local Exchange xDSL deployment, the line length X in Figure 6-1 and Figure 6-2 will typically be far less than 1 km. However, for a remote cabinet deployment, X can be up to several kilometers.

The transfer functions between the different ports of the splitter are shown in Figure 6-3 and Figure 6-4 and can be understood as follows:

- The transfer function from the POTS port to the LINE port and vice-versa is that of a low-pass filter.
- A high level of isolation is required from the xDSL port to the POTS port to prevent undesirable interaction between the xDSL transmission and any existing narrowband services, i.e. in both directions.
- The transfer function from the xDSL port to the LINE port and vice-versa is either that of a high-pass filter, or it MAY be all pass in nature, in the case where the full high pass filter function is implemented in the xDSL transceiver.

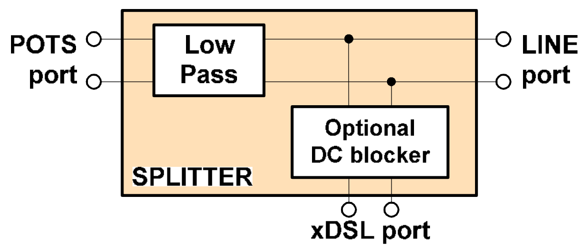


Figure 6-3: Structure of the xDSL master splitter

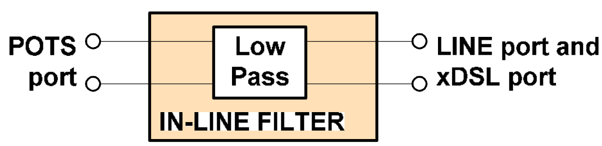


Figure 6-4: Structure of the xDSL distributed in-line filter

NOTE: The in-line filter can be implemented as an independent unit, separately from the xDSL transceiver. However, the master splitter can also be integrated with the xDSL termination unit. The splitter can also be integrated with the base band termination unit (e.g. POTS line card). In theory, one could even consider that the distributed version of the splitter is integrated inside a POTS telephone or other POTS terminal.

However, in general the actual location of the splitter and the topology of the connection of the "splitter box" are outside of the scope of this Technical Report.

6.2 Generic interworking testing diagram for xDSL over POTS

The interworking tests are double ended, with an actual xDSL over POTS system in the test environment.

In the interworking tests a pair of master splitters or one master splitter at the CO and a single splitter at the CPE is terminated with three phone model impedances at the POTS port. Alternately, a single or multiple in-line filters at the CPE side are terminated with a single phone model impedance at the POTS port. The splitters are interconnected with a line or line model. At the xDSL ports the xTU-C and xTU-R modems are connected respectively at the CO and the CPE side. For the in-line filter the line and xDSL port coincide and the xDSL modem and the line are put in parallel. Then signals are applied modeling the DC voltage and DC current and the AC signals of POTS, while also the xDSL modem pair is activated as needed. At both ends of the line stationary noise (modeling xDSL crosstalk among other things) are applied. The xDSL modems are initialized with a deterministic bitrate and a known margin. Then the xDSL links are monitored for Cyclic Redundancy Check (CRC) errors while stationary or transient POTS signals are applied at the POTS ports.

NOTE 1: The xTU-C modem, described as a baseline device in test 8.2 onwards, could either be realized with an integrated splitter high-pass function or be designed to use an external splitter high-pass function. This fact has to be considered from test 8.3 onwards for appropriate selection of baseline splitters and DC blocking capacitors, when different types of CO splitters are tested. It is the responsibility of the party performing the testing to insure the input impedance of the xTU-C and xTU-R modem will remain unaffected by replacement of a baseline splitter with a splitter under test (DUT) during the entire testing.

This implies that if the splitter DUT contains (or is missing) a set of DC blocking capacitors (as high pass) the baseline splitter also contains (or is missing) such a set of blocking capacitors. Furthermore, the xTU-C or xTU-R is selected such that its input impedance is correctly matched with the presence or absence of the DC blocking capacitors in the baseline filter and the splitter DUT.

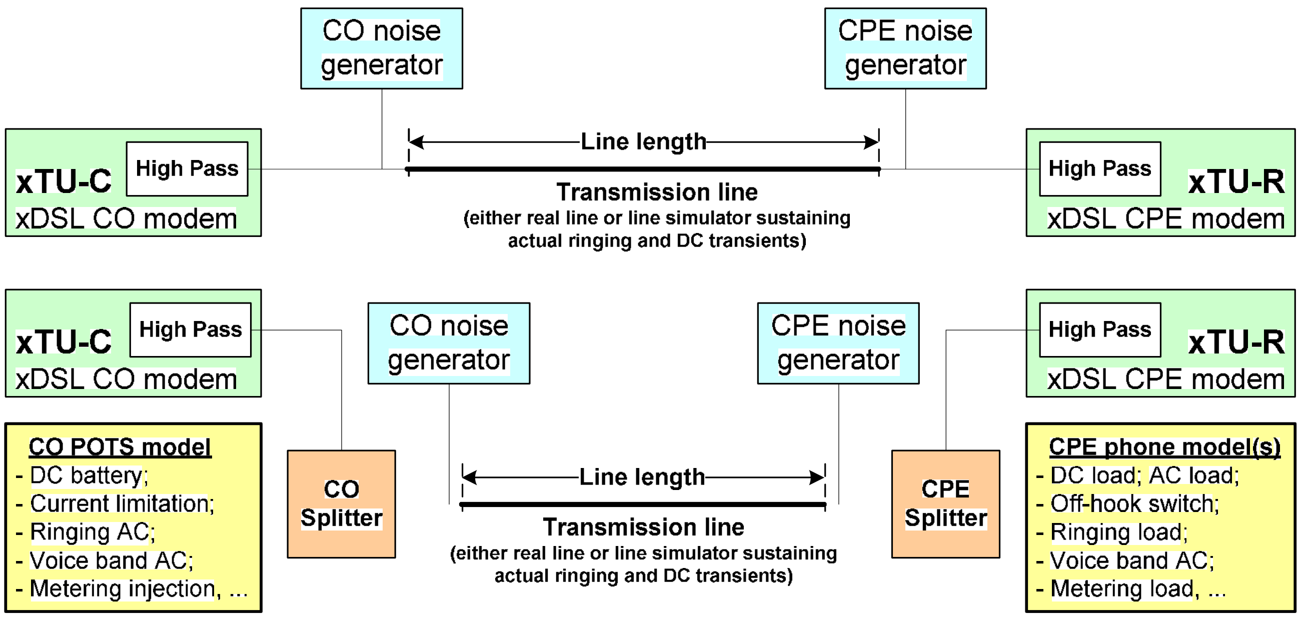


Figure 6-5: Double ended xDSL over POTS system interworking

In these double ended tests it is the intention to test the performance of the system. This means the following things for the system under test:

1) That the system is measured against an absolute requirement, because the CRC errors of the xDSL transmission stays below a specified maximal allowed CRC errors over the test period,

2) That the performance of the system under test is compared in an objective way, when the xDSL CRC errors (or the absence of errors) are measured over the test period. This will allow for the selection of the better system or those which combine a comparable CRC error performance with other qualities such as less complexity.

6.3 Generic Interworking Testing with In-Line Filters

Test on in-line filters could be done on a single device and on multiple parallel devices. Only the test with three multiple filters is mandatory.

6.3.1 Interworking Testing with a single In-Line Filter (Optional)

This is an optional test. Testing an in-line filter is performed by testing it as a single device, replacing a single master splitter. The in-line filter SHALL be loaded (when appropriate) with a single phone model on-hook and/or off-hook, as needed in the different tests. All tests of a single in-line filter SHALL be done exactly as for a single master splitter, except that the in-line filter SHALL be loaded with only a single phone model, and not with multiple ones as might be the case for the master splitter.

NOTE: The additional effects of the in-house wiring and how this is modeled and potentially tested are for further study.

6.3.2 Interworking Testing with multiple In-line Filters

The mandatory tests SHALL be restricted to the case of three parallel in-line filters as DUT. Connect the in-line filters in parallel to the same end point of the line or the line-simulator at the CPE side. The cabling to interconnect the three filters is specified in Section 5.3.

For tests with no DC or AC current (on-hook) or only AC current (continuous or cadenced ringing) the three parallel in-line filters are each loaded with a single on-hook telephone model representing a worst case ringer. For tests with DC current (continuous on-hook/off-hook) or AC and DC current (ring trip), all parallel in-line filters are loaded with an on-hook telephone model as described above for ringing, and a single in-line filter is passing the DC current, either with the off-hook phone model, permanently off-hook or toggling the hook switch.

NOTE: The additional effects of the in-house wiring and how this is modeled/potentially tested are for further study.

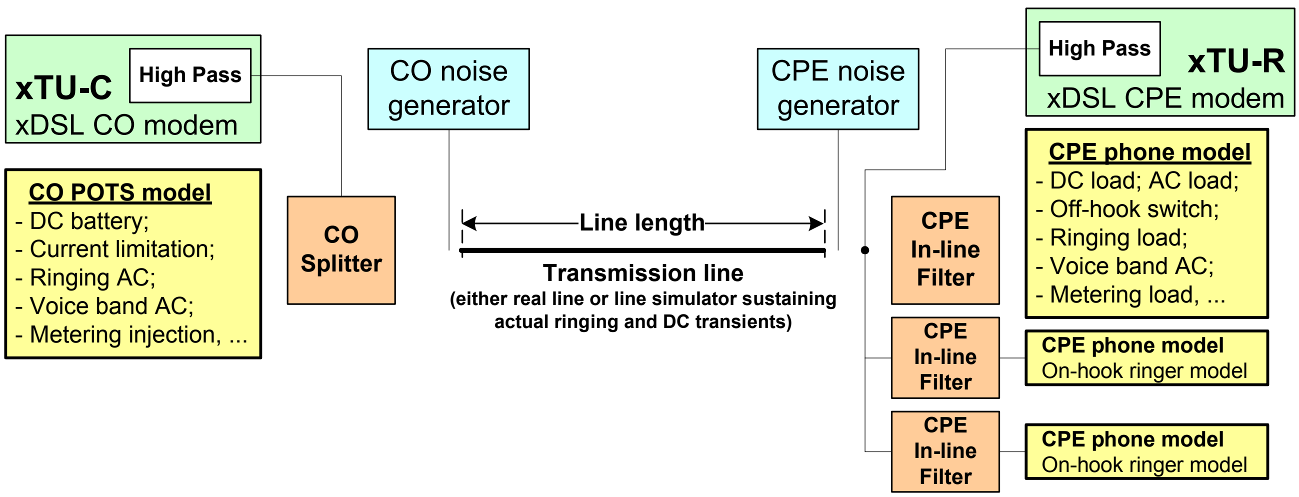


Figure 6-6: Interworking with Multiple In-Line Filters

7 POTS testing conditions (stationary and transient)

This Section contains the description of stationary and non-stationary POTS signals and their state diagrams needed to generate POTS test signals for testing the system. These POTS signals model worst-case effects caused by POTS noises injected by the POTS CO and CPE, which reach the xDSL systems via the splitters. The disturbing POTS signals can affect xDSL systems, when they propagate in spite of attenuation from the POTS port of a splitter to the local or the remote xDSL transceiver. These POTS noises can be very strong and either the splitter is unable to attenuate them sufficiently, or they excite non-linear behavior in some parts of the splitter, which could cause transient or even stationary disturbance or noises in the xDSL transceivers.

7.1 Stationary DC feeding conditions (on-hook and off-hook)

This Section contains stationary impedances and signaling models of the POTS circuits at the CO and the CPE side, when DC situations are stationary, i.e. on-hook with and without ringing, and off-hook to receive a call or to make an outgoing call attempt. Off-hook during ringing is considered a transient type of signal behavior and is handled in Section 7.3.

7.1.1 Stationary DC voltage situations and models of the CO side

All voiceband electrical requirements for typical networks, SHALL be met with a nominal steady state DC feeding voltage of 48 V, and it SHALL be modeled as varying in the range from 40 V to 56 V.

For networks with a boosted battery, the nominal steady DC feeding voltage is 60 V, and it SHALL be modeled as varying in the range from 50 V to 70 V.

For networks with short-haul POTS CO circuits, the nominal DC feeding voltage is 40 V, and it SHALL be modeled as varying in the range from 34 V to 46 V.

In the stationary model of the CO, DC voltages, currents, and stationary voiceband AC signals and impedances SHALL be applied with a feeding circuit. Such circuit is intended to merge DC and voiceband AC signals and impedances shielding these independent sources from one another. AC ringing signals are defined in Section 7.2.3.

Figure 7-1 below shows the equivalent circuit diagram of a feeding circuit. However, to reduce the complexity of the test set-up only the simplified feeding circuit defined in Section 7.3.1.1 in Figure 7-4 to Figure 7-7 SHALL be used for this purpose, with the switch in a fixed non-ringing position, i.e. to inject only DC voltage with the associated DC current.

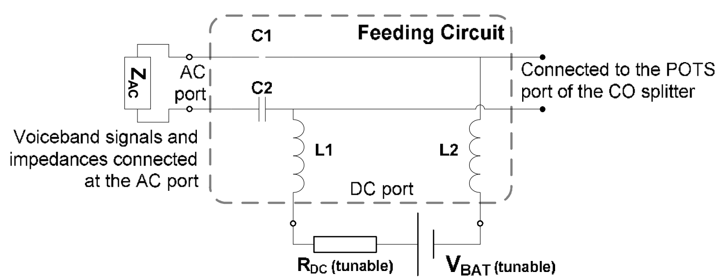


Figure 7-1: Feeding Circuit

Values as defined in Section 7.3.1.1: L1 = 165 mH, L2 = 165 mH, C1 = 2 µF, C2 = 2 µF

(Tolerance: L=10%, C=5%)

7.1.1.1 Stationary DC current models at the CO side in on-hook

On-hook electrical requirements of splitters SHALL be met with a steady state DC current of 0 to 10 µA.

NOTE: DC current in on-hook is normally in the order of a few µA, and the splitter does not add a significant amount to this value when a sustained on-hook situation is present for more than 30 s.

Additionally in certain networks there might be on-hook (voiceband AC) signaling requiring a DC loop current in the range of 0.4 mA to 2.5 mA flowing through the splitter.

7.1.1.2 Stationary DC impedances modeling the CO side in on-hook

The DC model of the on-hook CO impedance SHALL be identical to the off-hook impedance model, including current limiting devices to avoid unrealistic over current situations, needed for safety reasons during tests and able to deliver:

1) the off-hook current starts as soon as the DC impedance of the CPE POTS device changes to the off-hook state;

2) the on-hook current of at least 2.5 mA, needed to feed certain on-hook (AC) signaling CPE receivers.

7.1.1.3 Stationary DC current models of the CO side in off-hook

Off-hook electrical requirements of splitters SHALL be met with a steady state DC current of 13 mA to 80 mA.

NOTE: The 13 mA might be insufficient to allow regular telephones to work appropriately. For the purpose of testing the splitters however, this lower current limit will assure that the splitter will work appropriately even in situations with the lowest actual current found in the network. This lower bound of the current could also be needed to test active splitters, which have different states depending on the on-hook or off-hook state of the line and which use the current as an indication that the POTS CPE device is off-hook.

NOTE: It is recognized that in some networks steady state DC feeding currents of up to 100 mA or higher can occur. Similarly there are networks in which the maximal DC feeding current is limited, e.g. by the POTS SLIC. This might allow designs adapted to these specific conditions. It is optional to allow the splitter requirements to be reduced or enhanced to work up to lower or higher maximal steady state currents.

NOTE: By limiting the maximal current delivered in stationary DC situations it is not guaranteed that currents higher than this value will not pass through the line and the splitters. Indeed, in ring-trip conditions the DC is augmented with the ringing AC and the instantaneous voltages and current can surpass the stationary DC values. A splitter, which is tested at the maximal DC feeding current of 60, 80 or 100 mA will have to sustain peak currents well above 100 mA during ring-trip in certain circumstances.

7.1.1.4 Stationary DC impedances modeling the CO side in off-hook

Current limitation is achieved by a set of balanced resistances totaling 400 Ω, able to deliver the maximal off-hook current on the smallest DC load resistance. This is in line with the simplified feeding circuit defined in Section 7.3.1.1.

7.1.2 Stationary DC situations and impedances modeling the CPE side

The CPE side is modeled with the Z_{ring} in on-hook and Z_{trip} in off-hook, as shown in Figure 7-11 of Section 7.3.2.1.

NOTE: The termination is not perfect in the voiceband, but this will not impact the DSL band performance, which is checked primarily in the tests of Section 8.

7.1.2.1 Stationary DC impedances modeling a high-Ohmic CPE side on-hook

Normally when on-hook the POTS CPE device is considered as high-Ohmic, and it will draw a current less than 10 µA.

In the on-hook state the stationary DC impedance modeling the POTS device(s) SHALL be higher than 5 MOhm except for the case that an on-hook AC signaling is applied at voice frequencies from the CO side, during which certain terminals are allowed to draw an on-hook current specified in Section 7.1.1.1.

7.1.2.2 Stationary DC impedances modeling CPE side when off-hook

For the purpose of modeling, the steady state current is drawn by the POTS device modeled by the off-hook model of Section 7.3.2.1, which has a DC resistance ($R_{OH1} + R_{OH2}$) of 200 Ohms. No holding circuit is needed to decouple the AC and the DC impedances.

NOTE 1: For the purpose of varying the DC current to the minimum or maximum values, the 200 Ohm R_{DC} value can be replaced with a variable resistor. The minimum and maximum DC currents are defined in Section 7.1.1.3. This variant of the CPE model is for further study.

NOTE 2: In some cases the telephone is limiting the voltage at the entrance of the phone, while in other networks the telephones contain a current limiting device. However, this variability of the off-hook current (including even an electronic adjustment) is only relevant for the transient behavior of the POTS CPE device, which needs to be simulated in the interworking tests between xDSL and POTS transient signals.

7.2 Stationary AC Terminating impedances

The impedances in this Section are intended for voiceband only. The DC feeding conditions of the line SHALL be controlled separately, e.g. by inserting the appropriate DC feeding circuits as specified under Section 7.1.

7.2.1 Z_{AC} modeling a POTS CO, CPE or phone line

For requirements relating to voiceband frequencies the terminating impedances Z_{AC} at the CO side are defined in Table 7-1 below and are used in conjunction with the feeding circuit defined in Section 7.1.1. For the POTS termination at the CPE side the ringer model Z_{ring} is used in on-hook, while in off-hook the model Z_{trip} is used.

Table 7-1: CO and CPE On Hook/Off Hook Impedances

	On-hook	**Off-hook**
North American CO	Z_{AC} = 900 Ohm	Z_{AC} = 900 Ohm
European CO	$Z_{AC} = Z_R$ (defined in Figure 7-2)	$Z_{AC} = Z_R$ (defined in Figure 7-2)
North American and European CPE	Z_{ring} (defined in Figure 7-3)	Z_{trip} (defined in Figure 7-12)
The North America reference impedances have been taken from ATIS-0600016, T1 TRQ 10-2003, and T1.421-2001. The European reference impedance Z_R is defined in ETSI TS 101 952.		

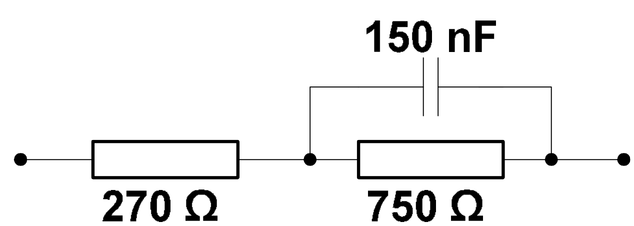


Figure 7-2: Impedance Z_R (Europe)

(Tolerance: R=1%, C=5%)

NOTE: In Europe, instead of Z_R, alternative models of reference impedances could be used when testing the splitter requirements according to this Technical Report.

7.2.2 Z_{ring}, impedance modeling a CPE ringer circuit (on-hook phone model)

Ringing load representing a maximal load of a single electronic CPE POTS device

For on-hook requirements in the presence of ringing signals the terminating POTS impedance Z_{ring} is used, modeling the terminal equipment on-hook. This impedance represents the minimum ringing load of the customer premises equipment that any network is assumed to be able to support. The Z_{ring} impedance is dependent on the ringing frequency.

For the purpose of modeling a group of POTS CPE devices while ringing, the following electronic model of the ringing circuit SHALL be used. It is applied permanently. It will be invisible for the voice signals due to the presence of the diode bridge, which masks the POTS voiceband AC signal up to 1.5 volts amplitude.

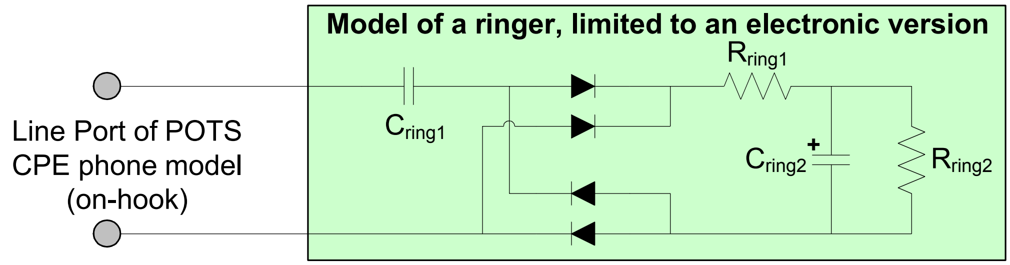


Figure 7-3: Z_{ring}, the electronic ringer model with diode bridge (on-hook phone model)

Table 7-2: Ringer Model Impedances

Ring Frequency (Hz)	R_{ring1} kOhm	R_{ring2} kOhm	C_{ring1} µF	C_{ring2} µF
20	2	2	2.2	47
25	2	2	2.2	47
50	2	2	1	25

(Tolerance: R=1%, C=5%, Power Rating of $R_{ring1\ a}$.and R_{ring2} is 0,25 W)

NOTE: Certain networks allow POTS CO circuits to be loaded with multiple telephones in parallel with a combined ringer impedance lower than 4 kOhm. Therefore, for the tests with continuous ringing and for dynamic tests with cadenced ringing the combined ringer impedance is lowered even more than 4 kOhm to three parallel Z_{ring} loads, to test the splitter with the largest possible AC current, while the POTS CPE devices are still on-hook.

7.2.3 Continuous AC ringing Signal Generator

For testing splitters with a continuous stationary AC signal the same generator SHALL be used as defined in Section 5.1 and implemented as defined in Section 7.3.1.1, with cadenced ringing injected. The ringing injecting switches do not toggle for continuous ringing.

7.3 Signals and terminations modeling POTS transients

The signals and impedances in this Section are intended for the transient testing of splitters. The intention of the combined DC and AC signal generators and their (potentially varying) impedances, is to model an actual "life-like" behavior of the POTS signals and circuits, when DC and/or AC transitions are occurring on the phone lines.

The DC voltages and currents are specified under Section 7.1.1. Similar to the stationary tests, the DC feeding conditions of the line are controlled by a dedicated DC feeding circuit at the CO and CPE sides but by dedicated signal sources. The difference is that when ringing is injected, it is cadenced.

7.3.1 Signals and terminations modeling transients at the CO

The signals and impedances in this Section model the transients of signals and impedances at the CO side of the line.

7.3.1.1 CO POTS model

Instantaneous DC currents and the steady state DC and AC current of the CO source SHALL never exceed the maximal allowed current, specified in Sections 7.1.1.1 and 7.1.1.3

NOTE: The instantaneous AC + DC currents of ring trip (off-hook during ringing) or cadenced ringing injection (at the CO) cannot be guaranteed to stay below the limits specified in Section 7.1.1.3, because the ringing AC voltage is added to the DC voltage of the battery. Furthermore, the instantaneous current, e.g. at off-hook, can also exceed the current limits specified in Section 7.1.1.3, because the load of the phone model is not purely Ohmic, which might enhance the current.

The DC feeding circuit is feeding the line with a resistor in series with a low pass coil, and terminating the voiceband with the correct AC impedance model with a DC decoupling capacitor (see Figure 7-4 through Figure 7-8).. Figure 7-4 and Figure 7-5 show parallel ringing injection and Figure 7-6 and Figure 7-7 show serial injection. All methods achieve the same results. The injection method chosen SHALL be used throughout the entire suite of tests.

NOTE 1: Either the serial or the parallel injection will result in identical behavior of the signals injected in the splitters and the line, provided that the voltages of both DC sources of the parallel method are the same.

NOTE 2: Polarity reversal at the instant of the ringing injection can be modeled by both the parallel and the serial injection. In parallel injection the voltages of the two sources have opposite polarity. In serial injection an extra crossover is added to connect the battery voltage to the ringing injecting switches, to achieve the voltage reversal when the switches toggle.

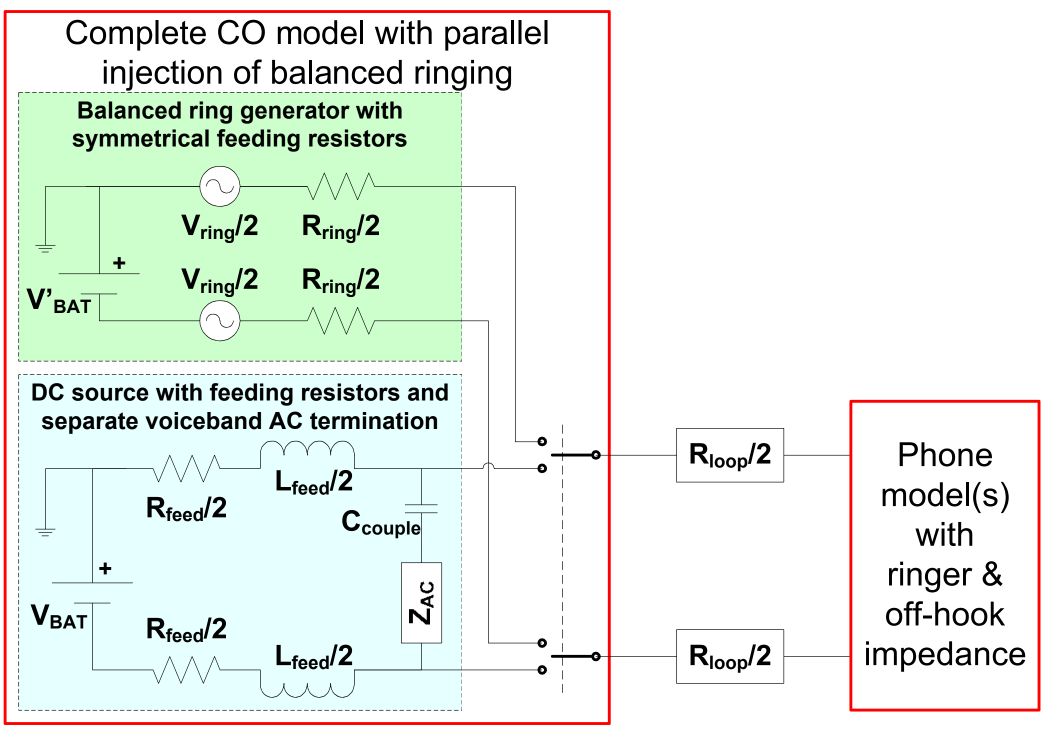


Figure 7-4: CO POTS model for DC and parallel, balanced ringing injection

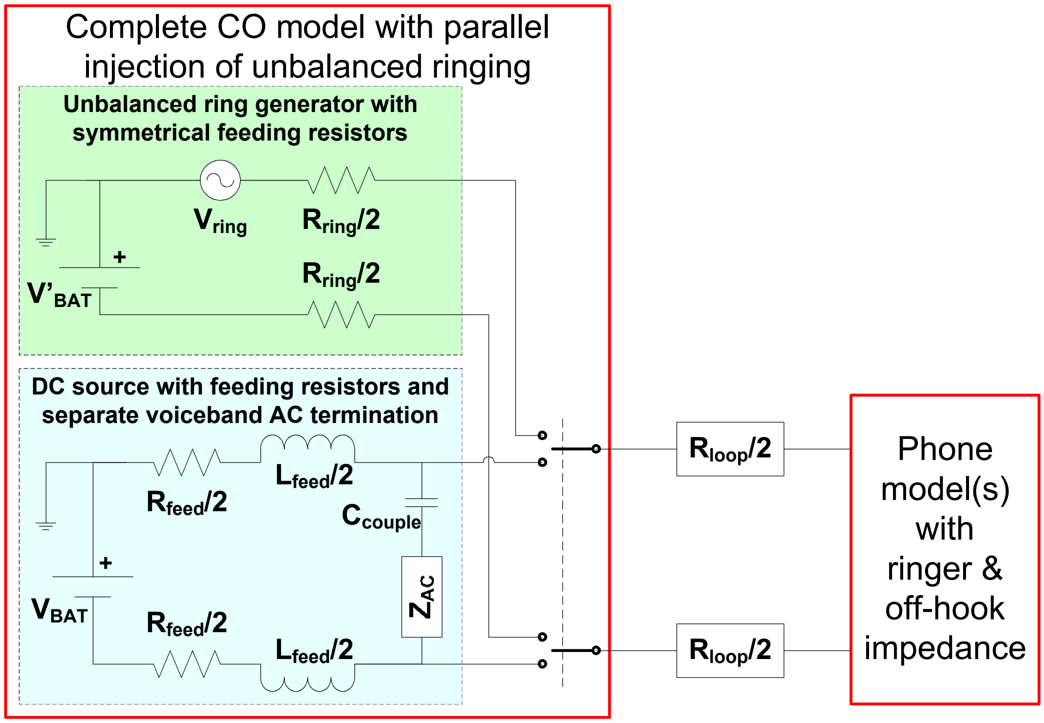


Figure 7-5: CO POTS model for DC and parallel, unbalanced ringing injection

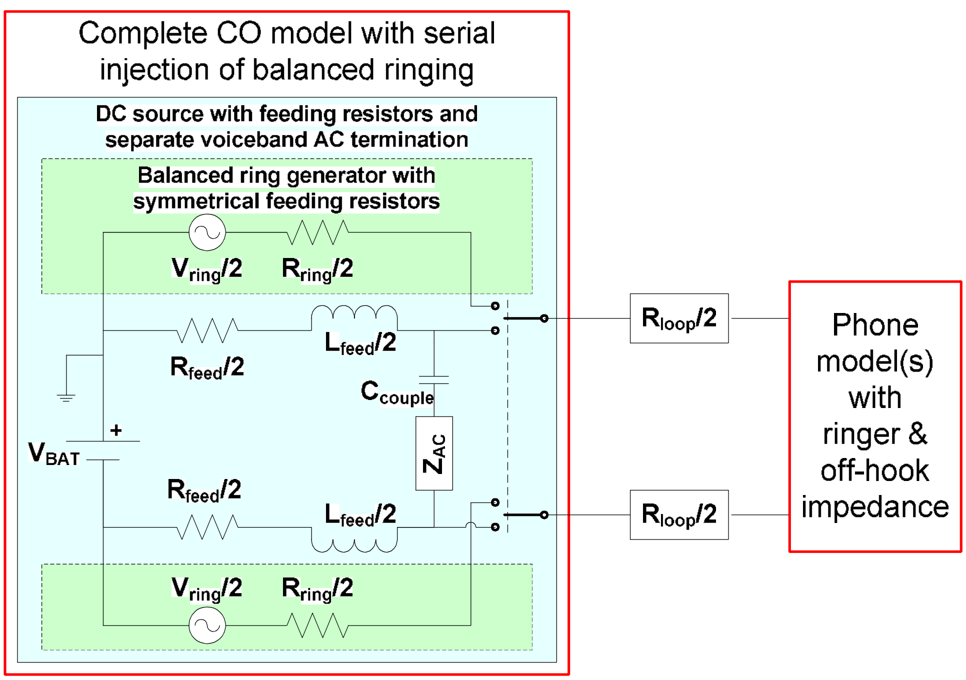


Figure 7-6: CO POTS model for DC and serial, balanced ringing injection

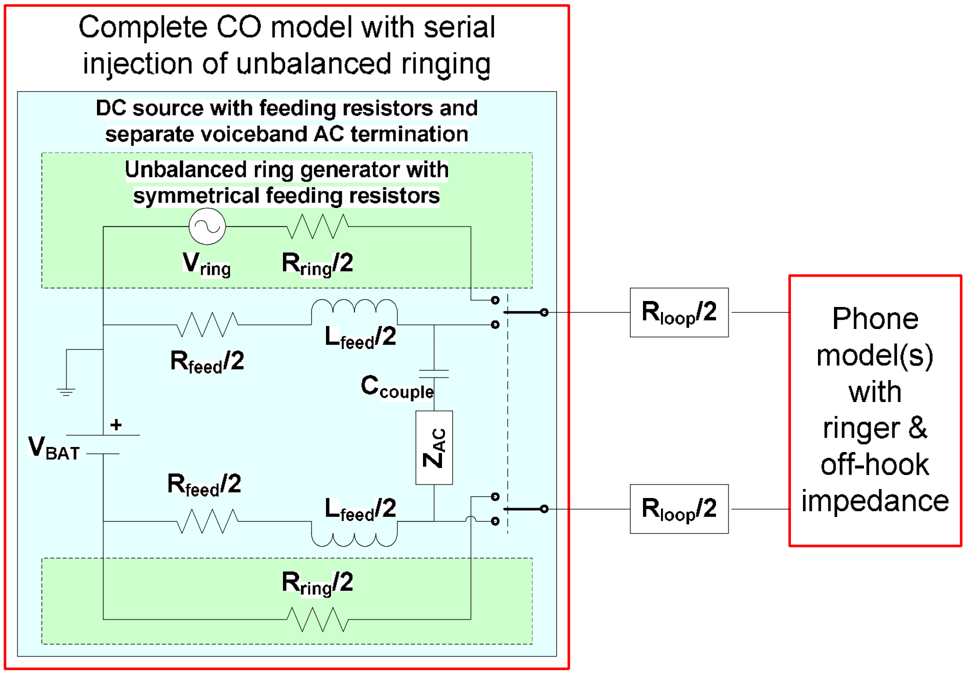


Figure 7-7: CO POTS model for DC and serial, unbalanced ringing injection

The components are as follows:
L_{feed} = 330 mH, i.e. an impedance at 300 Hz of 600 Ohm.
C_{couple} = 1 µF, i.e. an impedance at 300 Hz of 530 Ohm.

R_{feed} = 400 Ohm, diminished with the resistive DC part of the L_{feed} coils and switch/relay resistance

V_{ring} = 90 V RMS (see Table 5-6)

R_{ring} = 850 Ohm reduced by the internal DC impedance of V_{ring}, split in two equal halves.

V_{BAT} = V'_{BAT} = values as defined in Section 7.1.1. This voltage source SHALL not contain an electronic current limit less than 0.5 A, to model correctly the occasional excessive current peaks during transients.

NOTE: The two L_{feed}/2 coils could be realized with one or more transformers to improve the balance of the DC source. The DC resistance of the coils is subtracted from the R_{feed}.

Z_{AC} is the voiceband AC termination impedance model defined in Table 7-1.

Tolerance: R=1%, L=10%, C=5% (Power Rating of the components is the responsibility of the implementer of these circuits)

7.3.1.2 Cadenced ringing application at the CO

7.3.1.2.1 Ring Relay Cadencing:

Ringing is injected as a balanced or unbalanced signal, with balanced feeding resistors. The ringing injection is either in parallel with the DC feeding circuit or in series, as shown in Figure 7-4 through Figure 7-7.

Rather than cadencing the ringing bursts at the normal speed, the on and the off period could be made equal, and shortened. The minimum period for the ringing-on and the ringing-off periods SHALL be 500 ms.

7.3.1.2.2 "xDSL-friendly" cadenced ringing application at the CO

Normally "xDSL-friendly" ringing is applied, injected at zero-crossing or with some shaping. This type of ringing includes the normal DC + AC ringing and the DC-less ringing in a short-haul POTS CO.

For “xDSL-friendly” ringing the AC signal is injected on the line or removed from the line in the actual POTS CO with electronic switches. The impedance of the AC ringing source can be resistive, but SLICs also use electronic means to limit the current.

In the CO POTS circuit model used in this Technical Report, the balanced feeding resistors are specified in Section 7.3.1.1. Note that the feeding resistors R_{ring} are not able to limit the instantaneous current to a level below what is specified in Section 7.1.1.3. It is possible to inject the ringing at the zero crossing with electromechanical relays. However, this is difficult to implement.

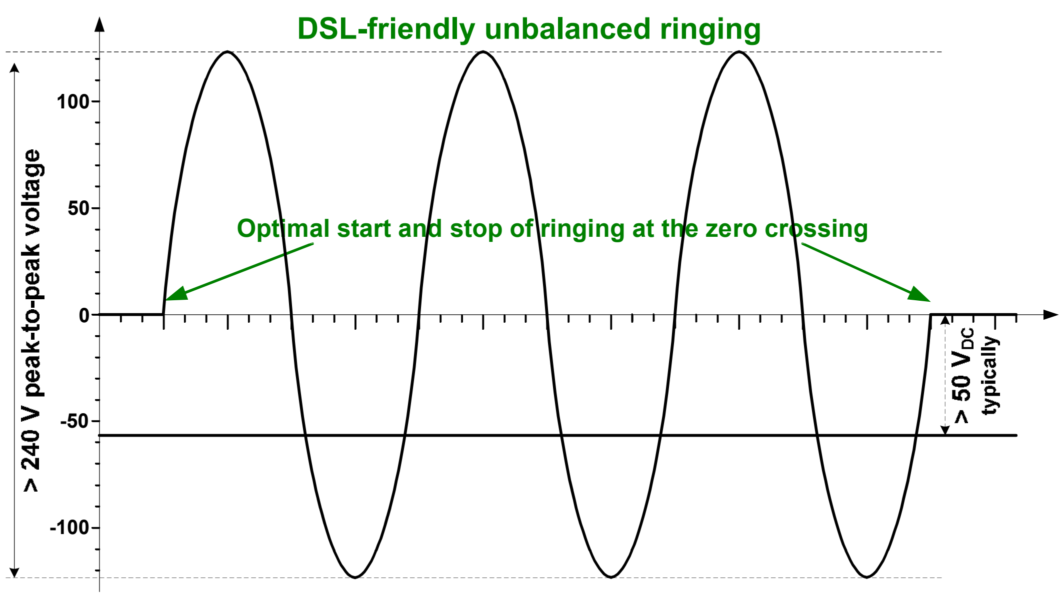
Therefore, to achieve xDSL-friendly ringing in a reliable way, it is recommended that electronic switches be used. A number of high-voltage SLIC devices can be used for that purpose. An example of an electronic switch is a Line Card Access Switch (LCAS). An LCAS is a common, special purpose IC that contains high-voltage switches for tip and ring line break, power ringing, line test access, test in access and ringing generator testing. They provide the necessary functions to replace all 2-Form-C electromechanical relays on analog and combined voice/data line cards found in the Central Office, Access and PBX equipment. LCAS ICs are commonly used in applications of VoIP Gateways, Central Office, Digital Loop Carrier, PBX systems, Digitally Added Main Line, Hybrid Fiber Coax, Fiber in the Loop, Pair Gain System and Channel Bank applications.

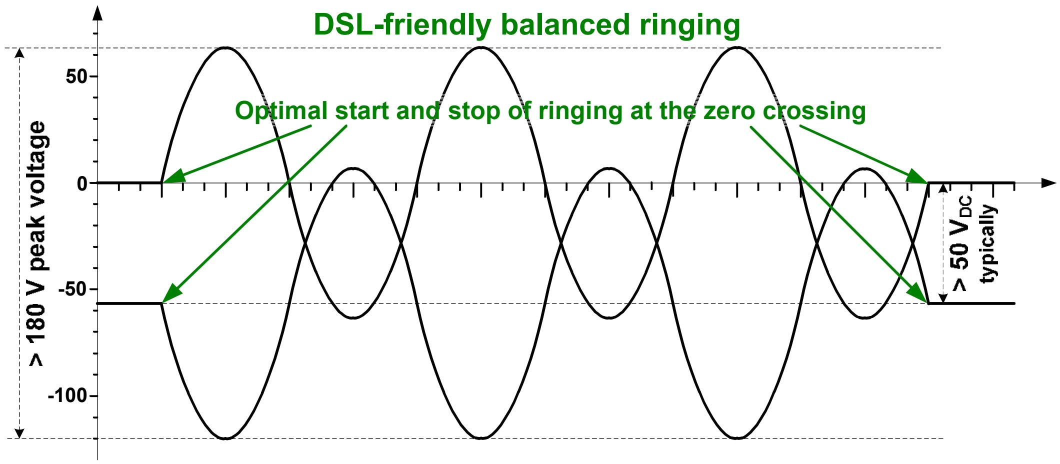
If used, the LCAS SHALL have the minimum requirements:

- Clean, bounce-free switching
- Eliminate the need for additional zero-cross switching circuitry
- DC current limit > 70 mA
- Dynamic Current Limit > 2.5 A ($t < 0.5$ µsec)

For AC + DC ringing the switches either inject or remove the AC ringing to to the DC battery feed. This happens at the zero crossing of the AC signal, or by shaping the AC signal with a window function at start and end.

For the AC only ringing, the AC is applied to the line, replacing the DC voltage, when the AC signal passes the level of the DC feed.





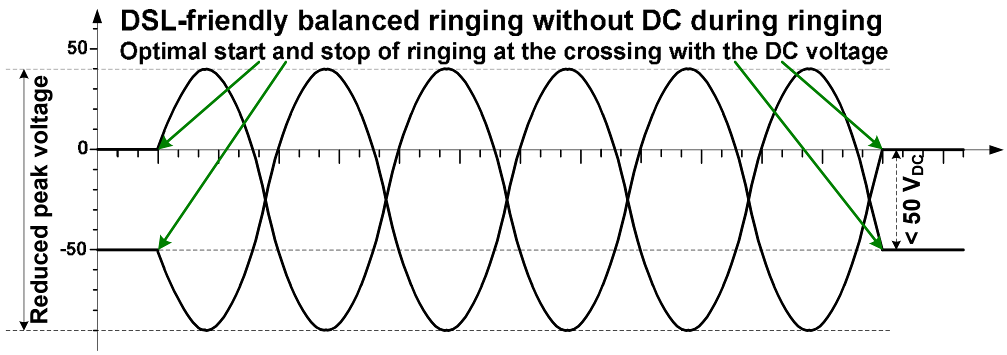


Figure 7-8: Three example cases of xDSL-friendly ringing; unbalance with DC, balanced with DC, and balanced without DC

NOTE: Unbalanced ringing without DC during ringing: this kind of signal does not exist in regular systems. The main purpose of sending ringing without DC is to reduce the maximal signals at the SLIC outputs, which requires a balanced ringing signal.

NOTE: The two curves in each figure show the voltage a-wire to earth and b-wire to earth respectively, and the instantaneous voltage between a- and b- wire is the difference between these voltages.

7.3.1.2.3 Cadenced ringing application at the CO with "xDSL-unfriendly" transients

In some circumstances, the ringing is not added to the DC of the battery at the zero crossing of the AC wave. This can happen when an electro-mechanical relay is used. This form of ringing is essentially "xDSL-unfriendly". In practice, the ringing voltage can start at any phase angle within a period. Normally there is no fixed relationship between the start and end of the ringing burst and the phase of the ringing AC signal. Over a long number of ringing bursts, all possible phase angles will have been used at the start and the end of the burst.

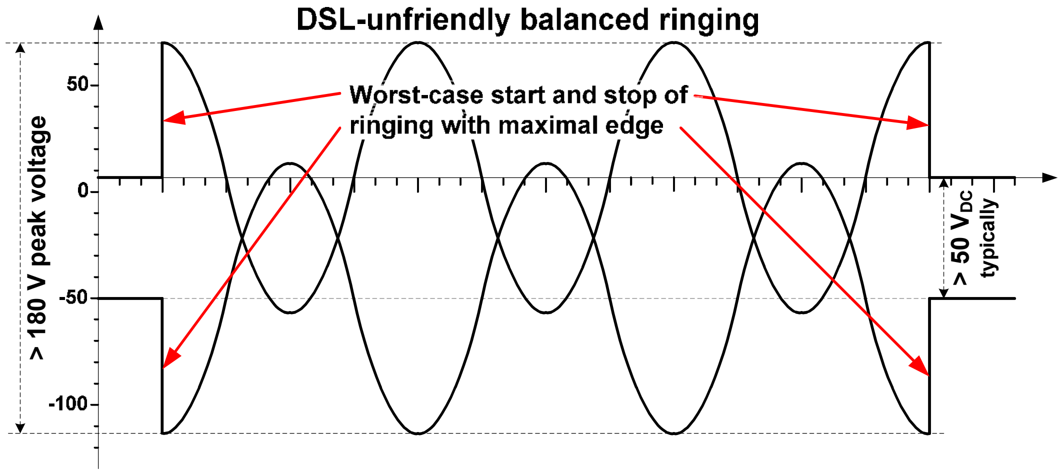


Figure 7-9: Example of xDSL-unfriendly ringing: balanced with DC

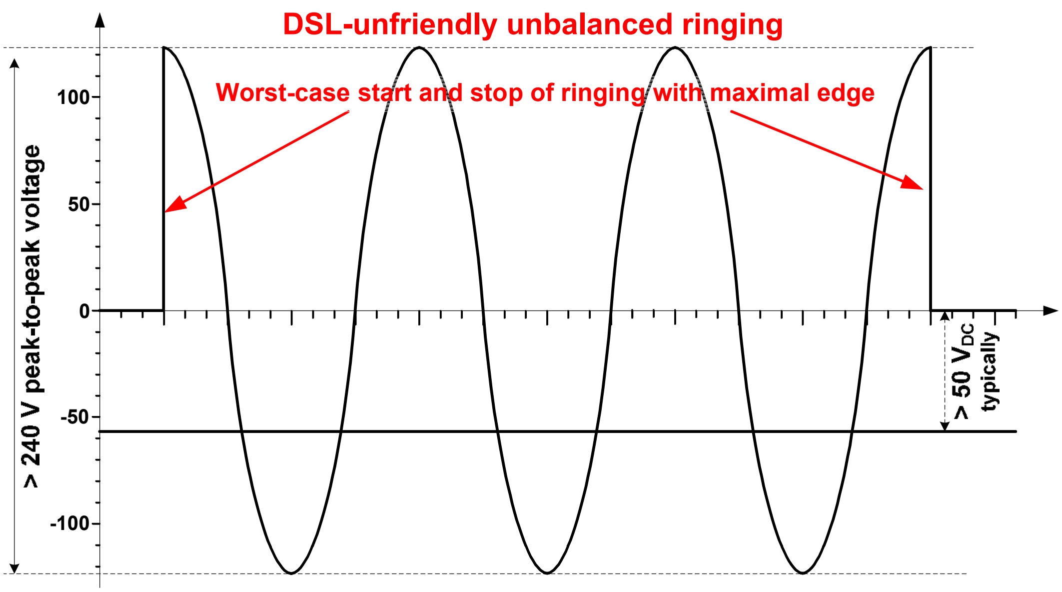


Figure 7-10: Example of xDSL-unfriendly ringing: unbalanced with DC

NOTE: xDSL unfriendly ringing without DC: This kind of signal does not exist in regular systems. The main purpose of sending ringing without DC is to reduce the maximum signals at the SLIC outputs. SLICs are capable of injecting xDSL friendly ringing.

7.3.1.2.4 Ring relay modeling at the CO for reproducibility

Applying xDSL-unfriendly ringing signals:
The preferred method of applying xDSL unfriendly ringing signals is with an electro-mechanical relay, allowing for the fast and reproducible application and removal of the AC ringing signals away from the zero crossings. The selected relay SHALL have a bounce time of shorter than 0.5 ms.

Applying xDSL-friendly ringing signals:
The preferable method of applying xDSL-friendly ringing signals is with an electronic switch such as an LCAS, which are activated at the zero crossing of the ringing waveform.

For reproducibility of the xDSL-unfriendly ringing the combined DC + AC ringing signal is modeled by applying and removing the ringing signal with a sliding phase, which will cause the voltage jump to vary between the most gentle position at the zero crossing and the maximal possible amplitude visiting all possible phases between 0 and 360 degrees. The sliding phase increment is minimally 360/n, where n is the number of ringing burst injected over the complete test.

If the xDSL-unfriendly ringing signal is injected by an electronic switch, it SHALL be applied with a rise time shorter than 10 µs, to ascertain that there is a sufficient and reproducible amount of noise contained in it. If an electro-mechanical switch or relay is used, no requirements on the rise time are specified.

NOTE: As a PSTN CO often contains electro-mechanical relays for ringing injections, the optimal interworking test consists of injecting the ringing through such relay. It is clear that it is not easy to couple the instance of the ringing application or removal (and also the ring-trip in the next Section) with the phase of the ringing AC signal. This is caused particularly by the delay of the relay movement, and the extra effect of the relay contact bouncing. Therefore, the application of the ringing at a particular phase (e.g. at the zero-crossing or at the worst case phase position) could be difficult. However, as the delay of the relays is constant, it is possible to inject the ringing and stop the ringing with a sliding phase, which slides through all the possible phase positions between 0 and 360 degrees. Furthermore, it is also possible to do the ring trip with a similar sliding phase, which visits all the possible phase angles between 0 and 360 degrees. In this way all the phase angles are used gradually and it is not necessary to randomize the ringing start or the ring trip instance. Furthermore it was also shown that by measuring the delay of the relay, it is possible to generate the ringing start with an electromechanical relay, such that it is always very close to the zero crossing and therefore, the start is sufficiently xDSL friendly.

7.3.1.3 Ring-trip modeling at the CO and its reproducibility

In normal circumstances a CPE off-hook condition will cause the CO to remove the ringing within 200 ms.

The ring-trip modeling SHALL be deterministic, i.e. there SHALL be a coupling between the CPE device model and the ring relay. When a control signal is applied to force the off-hook impedance of the CPE side, it SHALL be followed by a second control signal forcing the ring relay to remove the ringing.

Therefore, when during ringing the CPE POTS device is modeling an off-hook by applying a low impedance, the CO ringing model SHALL remove the ringing signal with a delay of 200 ms ±20 ms ±(½ period of the ringing frequency).

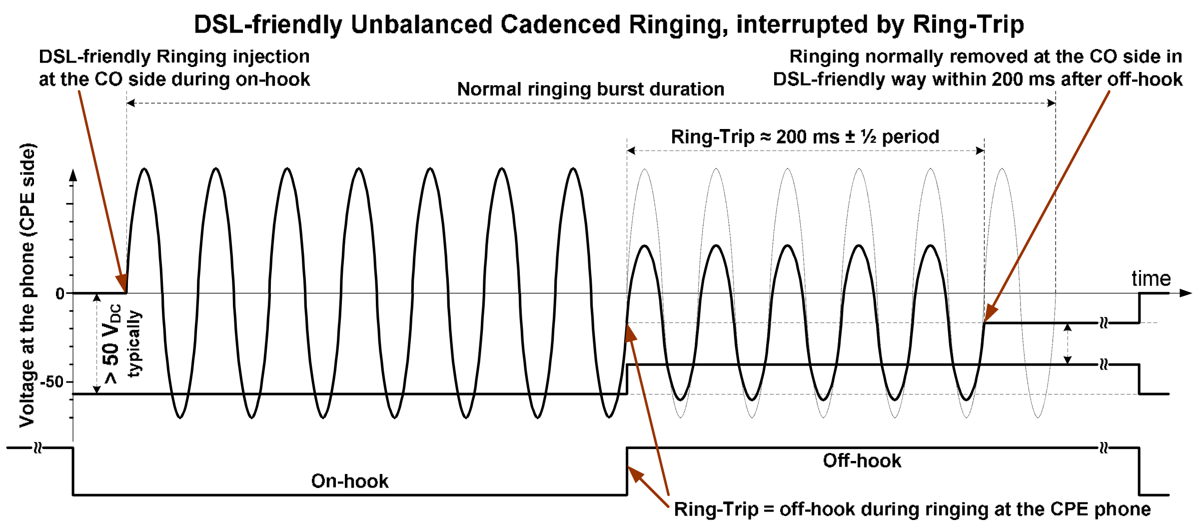


Figure 7-11: Ring-trip detection modeled by deterministic removing of the ringing AC

NOTE: The ½ period of the ringing frequency is added to allow the removal of the ringing signal at the zero crossing or with a xDSL-friendly shape.

NOTE: If the POTS CO has particular properties, (a faster or slower ring-trip detection) this can be modeled by advancing or delaying the ring-trip, even making it line length dependent or even DC and/or AC current dependent.

NOTE: As an alternative the ringing generator could detect the actual ring-trip current (DC and/or AC). However, this is not recommended, as it reduces the reproducibility of the instance of the removal of the ringing by the ringing relay.

7.3.2 Z_{trip} termination modeling transients at the CPE

The signals and impedances in this Section model the transients of signals and impedances at the CPE side of the line. The DC current is supplied by the DC CO models of Section 7.3.1. The transient behavior of the current results from a change in the switch state within the Z_{trip} CPE POTS model.

7.3.2.1 Z_{trip}, the phone off-hook impedance modeling DC and ringing AC transients

The phone transition from on-hook to off-hook can happen when the line is quiescent (outgoing call attempt) or when an incoming call is signaled with the ringing. The off-hook while the line is ringing can happen during the ringing bursts or in between them. Furthermore, the actual ring-trip instance (potentially while AC ringing continues) can also happen at various phase angles relative to the start of the period of the ringing AC signal.

The on-hook ringer model is defined in Section 7.2.2, Figure 7-3.

For the purpose of modeling a single POTS CPE device transitioning from on-hook to off-hook and back, Figure 7-12 and the values below are specified.

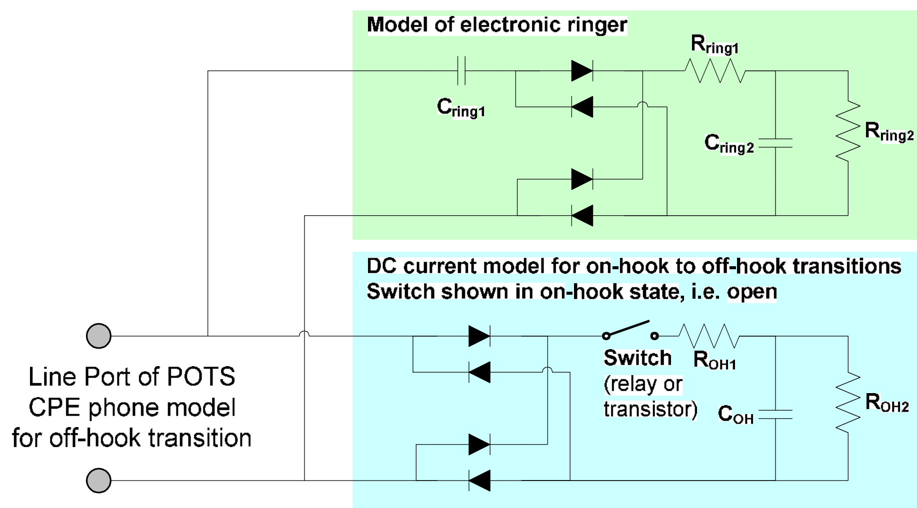


Figure 7-12: Model of Z_{trip} for off-hook transition (also useable for off-hook during ringing)

The components R_{OH1}, R_{OH2} and C_{OH} in Figure 7-12 are labeled "OH", which stands for **O**ff-**H**ook. The switch is shown in the on-hook state, i.e. open. The following values are defined for the components, ignoring the voiceband AC impedance:

R_{OH1}, = 50 Ohm; C_{OH}= 10 µF; R_{OH2} = 150 Ohm or more, to limit the steady state current if necessary.

The suggested minimum power rating for ROH1 and ROH2 is 5 W.

(Tolerance: R=1%, C=5%)

7.3.2.2 Regular off-hook-switch modeling for reproducibility

There are no issues of reproducibility of the regular off-hook/on-hook event. The timing of the off-hook transition is not relevant when only DC is present on the line. The use of a fast electronic switch or an electromechanical relay is equivalent. The fast electronic switch SHALL have a rise time less than or equal to 10 µs.

7.3.2.3 Ring trip off-hook modeling at the CPE for reproducibility

For ring trip, i.e. the off-hook while ringing AC is present on the line, the timing of the off-hook instance relative to the ringing AC phase will affect the noise transients created. If the off-hook happens when the voltage on the line is at its peak the resulting noise will be much worse than when the combined AC + DC signal is crossing through zero. In practice, the off-hook event can occur at any phase angle within a ringing period. Normally there is no fixed relationship between the off-hook event and the phase of the ringing AC signal. Over a large number of off-hook events, all possible phase angles SHALL have occurred.

For reproducibility of the off-hook during ring trip is triggered with a sliding phase relative to the period of the AC ringing signal. This will cause the transients to vary between the gentlest case at the zero crossing and the maximal possible amplitude. The test SHALL visit all possible phases between 0 and 360 degrees, with phase increments of minimally 360/n where n is the number of transients in the complete test.

- Although it MAY be modeled with an electronic switch to avoid non-reproducible bouncing, an electro-mechanical relay is preferable to allow for short rise time. The selected relay SHALL have a bounce time of shorter than 0.5 ms.

- If implemented with and electronic switch, the change of the impedance of the electronic switch SHALL have a rise time less than or equal to 10 µs, to ascertain that the sudden current and voltage changes are sufficiently rapid and containing a reproducible amount of noise within them.

- The off-hook instance is a ring-trip event relative to a ringing signal that uses a sliding phase (minimally 360/n, where n=60).
- The on-hook and off-hook durations have the following properties:
  - 500 ms ≤ on-hook duration ≤ 1 s
  - 500 ms ≤ off-hook duration, without any upper bound specified
- Off-hook and ringing are coupled (as in Figure 7-13), such that:
  - Ringing starts only when the phone is on-hook.
  - Ringing signal removal is delayed relative to the off-hook by 200 ms ± 20ms ± ½ period of the ringing frequency.
  - The timing can be adjusted to tune the total duration, without increasing the ringing or the ring-trip, by increasing the off-hook duration >> 500 ms.

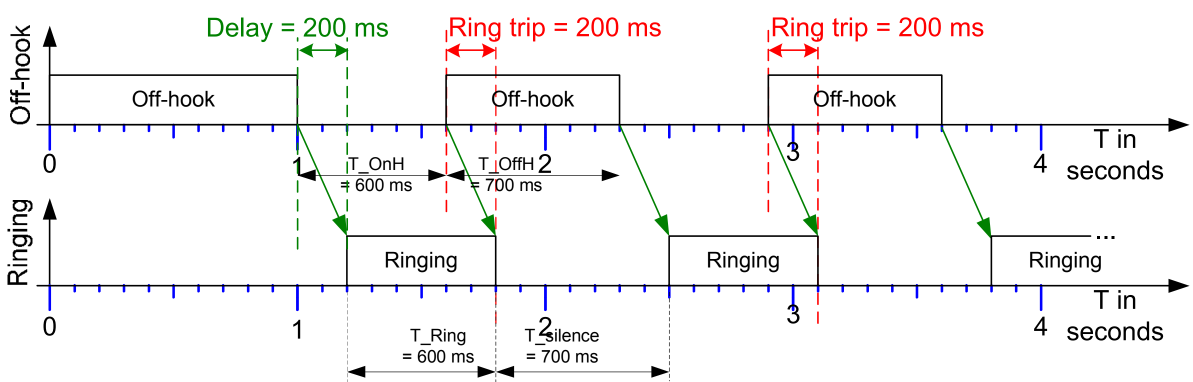


Figure 7-13: typical off-hook / on-hook transitions coupled to the ringing

- The ring-trip event is defined as the period from the CPE going off-hook during ringing to the removal of the ringing signal This event will contain:

  - The off-hook discharge of the phone line (potentially >500mA)
  - An off-hook with the ringing signal present of 200 ms, with a periodic over current of up to 180 mA on the off-hook phone model.

- The minimum duration of the on-hook with ringing present interval (medium current peaks, up to 180 mA) is 220ms ± ½ period of the ringing frequency.

NOTE: The sliding phase triggering of the off-hook during ringing is used, because it is not easy to couple the ring trip off-hook instance of a relay with the phase of the ringing AC signal. This is caused particularly by the unknown (but constant) delay of the relay movement, and the extra effect of the relay contact bouncing. Therefore, the application of the ring trip at a particular fixed phase (e.g. at the zero-crossing or at the worst case amplitude of the DC + ringing AC) will be difficult, if not impossible. Therefore, rather than modeling the ring trip at a fixed phase, it is much easier to generate the off-hook with a sliding phase, such that multiple phase angles between 0 and 360 degrees will be visited over the full duration of the test. This will make a ring trip test with sliding phase representative of a “random” ring trip event, with unknown phase.

8 Detailed dynamic/transient transmission test set-up

8.1 General test set-up

8.1.1 General test goal

The goal of these tests is either to validate a DUT using a system according to pass-fail criteria, or when run as relative tests, to compare DUTs within the same system.

8.1.2 General test configuration

The general test set-up reference model is shown in Section 6, Figure 6-5, i.e. with two xDSL transceivers, lines or line models, and two splitters.

The splitters at the CO are terminated with POTS CO models, capable of injection POTS signals or transients if required, including DC, voiceband AC, ringing and cadenced ringing.

The loop is terminated with a CPE splitter terminated at its POTS port by telephone models, containing three ringer impedances and one off-hook impedance, also causing transients on-hook to off-hook and back.

The loop could also be terminated with CPE in-line filters. In this case it is mandatory that there are three in-line filters connected in parallel on the line side. The DSL ports SHALL be terminated as follows: one with an off-hook impedance causing transients from on-hook to off-hook and back (Z_{trip}) and the other two in-line filters SHALL be terminated with an on-hook impedance (Z_{ring}). Throughout this document wherever the term “CPE splitter lowpass” is used the term “CPE in-line filter” can be substituted. Optional tests with a single in-line filter terminated with a single off-hook impedance causing transients from on-hook to off-hook and back (Z_{trip}) can be performed.

When comparative tests are performed, different DUT splitters are placed at one end of the loop, while all other baseline devices are kept the same.

Tests SHALL be performed according to the general procedure described in each Section. Some tests do not require all loops as test cases.

Table 8-1: VDSL2 Test Loops

VDSL2 Test Loops	North America 26 AWG (or equivalent)	Europe 0.4 mm (or equivalent)
VDSL2 Loop 1	300 ft	100m
VDSL2 Loop 2*	1000 ft	300m
VDSL2 Loop 3*	1800 ft	550m
VDSL2 Loop 4	3000 ft	1000m
*Note: These are the only loops required for the Data Rate Performance Test in Section 8.10.		

In order to reduce excess margin in the US for the ADSL2plus in the interleaved mode, configure the MAXNOMATPus for the loop lengths as indicated in Table 8-2. If tests are performed on other loop lengths other than Table 8-2 then the MAXNOMATPus is configured based on a linear interpolation in dB as shown in Figure 8-1.

For ADSL2plus in fast mode MAXNOMATPus is 12.5 dBm.

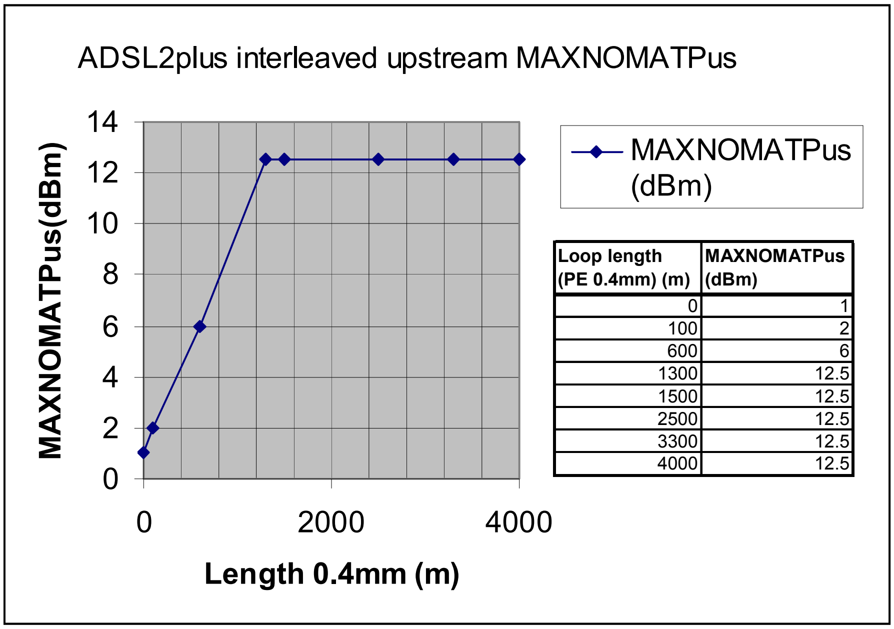


Figure 8-1: ADSL2plus interleaved upstream MAXNOMATPus

Table 8-2: ADSL2plus test loops

ADSL2plus Test Loops	North American Loop 26 AWG (or equivalent)	European Loop 0.4 mm (or equivalent)	MAXNOMATPus (interleaved only)
ADSL2plus Loop 1	300 ft	100m	2 dBm
ADSL2plus Loop 2	2000 ft	600m	6 dBm
ADSL2plus Loop 3	5000 ft	1500m	12.5 dBm
ADSL2plus Loop 4	8000 ft	2500m	12.5 dBm
ADSL2plus Loop 5	11000 ft	3300m	12.5 dBm

8.1.3 General test procedure

The xDSL modem SHALL initialize with a minimum of 4 dB margin on a test loop with real cable or a line simulator.

Injection of AWGN noise (i.e., –140 dBm/Hz at both CPE and at CO side) SHALL be used to make the tests reproducible and representative of the actual deployment. On short loops, i.e. low loop attenuation, a known condition exists where the noise injection at both ends becomes additive. For the purpose of these tests, this condition is considered acceptable.

For testing ADSL2plus triple play splitters in interleaved mode, the ADSL2plus modems SHALL be configured in Rate Adaptive Startup, and with the following settings:

Table 8-3: ADSL2plus settings, triple play, interleaved only

ADSL2plus Triple Play Modem Settings	Downstream	Upstream
MINSNRM	0 dB	0 dB
TARSNRM	6 dB	6 dB
MAXSNRM (NOTE 2)	511	511
INP_min	2 symbols	2 symbols
FORCEINP (NOTE 1)	TRUE	TRUE
Delay_max	8 ms	8 ms
Min NDR	5 Mbit/s	512 kbit/s
Max NDR	30 Mbit/s	30 Mbit/s

NOTE 1: This parameter indicates that the ATU-R receiver SHALL set the impulse noise protection (INP) to the value computed as defined in Table 7-7 of G.992.3.

NOTE 2: The value 511 is a special value, indicating that the MAXSNRM value is effectively infinite, as described in Section 8.5.3.2/G.992.3 (and in Section 7.3.1.3.3/G.997.1). If the DSLAM does not accept the 511 value, then input the highest possible value for MAXSNRM.

NOTE 4: For testing ADSL2plus triple play splitters in fast mode, the settings of HSI splitters apply.

For testing VDSL2 triple play splitters in interleaved mode, the VDSL2 modems SHALL be configured in Rate Adaptive Startup, and with the following settings:

Table 8-4: VDSL2 settings, triple play, interleaved only

VDSL2 Triple Play Modem Settings	Downstream	Upstream
MINSNRM	0 dB	0 dB
TARSNRM	6 dB	6 dB
MAXSNRM (NOTE 2)	$FFFF_{16}$	$FFFF_{16}$
INP_min	2 symbols	2 symbols
FORCEINP (NOTE 1)	TRUE	TRUE
Delay_max	8 ms	8 ms
Min NDR	25 Mbit/s	2Mbit/s
Max NDR	150 Mbit/s	150 Mbit/s

NOTE 1: This parameter indicates that the VTU-R receiver SHALL set the impulse noise protection (INP) to the value computed as defined in Section 9.6/G.993.2.

NOTE 2: The value $FFFF_{16}$ is a special value, indicating that the MAXSNRM value is effectively infinite, as described in Section 12.3.3.2.1.1/G.993.2 (and in Section 7.3.1.3.3/G.997.1). If the DSLAM does not accept the $FFFF_{16}$ value, then input the highest possible value for MAXSNRM.

NOTE 3: UPBO is off. Testing with UPBO is for further study.

NOTE 4: For testing VDSL2 triple play splitters in fast mode, the settings of HSI splitters apply.

For testing HSI and in-line filters, the modems SHALL be configured in Rate Adaptive at Startup with the following settings:

Table 8-5: ADSL2plus and VDSL2 margins and speeds for HSI splitter and in-line filters

ADSL2Plus HSI and In-Line Filters	Fast		Interleaved	
	Downstream	**Upstream**	**Downstream**	**Upstream**
MINSNRM	0 dB	0 dB	0 dB	0 dB
TARSNRM	6 dB	6 dB	6 dB	6 dB
MAXSNRM (NOTE 1)	511	511	511	511
INP_min	0 symbols	0 symbols	2 symbols	2 symbols
FORCEINP (NOTE 2)	N/A	N/A	TRUE	TRUE
Delay_max (NOTE 3)	S1	S1	8 ms	8 ms
Min NDR	32 kbit/s	32 kbit/s	32 kbit/s	32 kbit/s
Max NDR	30 Mbit/s	30 Mbit/s	30 Mbit/s	30 Mbit/s
VDSL2 HSI and In-Line Filters	**Fast**		**Interleaved**	
	Downstream	**Upstream**	**Downstream**	**Upstream**
MINSNRM	0 dB	0 dB	0 dB	0 dB
TARSNRM	6 dB	6 dB	6 dB	6 dB
MAXSNRM (NOTE 1)	$FFFF_{16}$	$FFFF_{16}$	$FFFF_{16}$	$FFFF_{16}$
INP_min	0 Symbols	0 Symbols	2 symbols	2 symbols
FORCEINP (NOTE 2)	N/A	N/A	TRUE	TRUE

Delay_max (NOTE 3)	S1	S1	8 ms	8 ms
Min NDR	128 kbit/s	128 kbit/s	128 kbit/s	128 kbit/s
Max NDR	150 Mbit/s	150 Mbit/s	150 Mbit/s	150 Mbit/s

NOTE 1: The value 511, and $FFFF_{16}$, is a special value, indicating that the MAXSNRM value is effectively infinite, as described in Section 8.5.3.2 of G.992.3, and 12.3.3.2.1.1 of G.993.2, (and in Section 7.3.1.3.3 of G.997.1). If the DSLAM does not accept the $FFFF_{16}$ value, then input the highest possible value for MAXSNRM.

NOTE 2: This parameter indicates that the ATU-R and VTU-R receiver SHALL set the impulse noise protection (INP) to the value computed as defined in Table 7-7 of G.992.3 and in Section 9.6 of G.993.2, respectively.

NOTE 3: The value 'S1' is a special value indicating that $S \leq 1$ and $D = 1$ (see G.997.1 Section 7.3.2.2)

8.1.4 General test checks

For different xDSL latency paths (e.g. fast and interleaved) the effect on the xDSL transmission are characterized, for upstream and downstream directions, as:

- A temporary or permanent loss of margin, with or without coding violation errors.
- Coding violation errors, characterized as the actual BER or a count of affected data blocks with CRC error or errored seconds.
- A loss of synchronization followed by retraining with original capacity without margin reduction.
- A loss of synchronization followed by retraining with original capacity but margin reduction.
- A loss of synchronization followed by retraining with reduced capacity.
- A loss of synchronization followed by incapability to retrain even at reduced capacity.

8.1.5 Expected results

A (temporary) margin reduction is observed, which can be characterized.

A (temporary) appearance or increase of the coding violation errors is observed, which can be characterized.

Synchronization failures, retraining or incapability to retrain are observed.

For absolute tests the observations are compared with the absolute performance requirements.

For relative tests the different devices under test are ordered according to the observed performance results.

Table 8-6: Overview of Tests

Overview of Interworking Tests of the System and Transients														
TEST		DC			Ringing		Transient	Splitters		POTS Models		DSL Interleaved/Fast		
Section	Test name	DC Voltage	DC Current	Type of DC Transients	Ringing Voltage	Max. peak ringing current (AC +DC)	Location of DC transients	# Baseline splitters	# DUT (Splitters) present	CO POTS Model Present	Phone Model	# Baseline DSL modems	Minimum DSL margin	Crosscheck or Baseline Case
8.2	Lab calibration test without splitters	--	0	--	--	--	--	0	0	--	--	2	4dB	**X**
8.3	Continuous hook – State test using baseline splitters	56V	0 → 80 mA	--	--	--	--	2	0	Case 1 DC only	CPE Case 1 or Case 2	2	4 dB	**X**
8.4	Continuous hook state test (with a splitter as a DUT	56V	0 → 80 mA	--	--	--	--	1	1	CO Case 1 DC only	CPE Case 1 or Case 2	2	4 dB	--
8.5	Continuous ringing test with baseline splitters	56V	0	--	YES	< 60 mA	--	2	0	CO Case 2 Ringing only	CPE Case 2 Ring load	2	4 dB	**X**
8.6	Continuous ringing test (with a splitter as a DUT)	56V	0	--	YES	< 60 mA	--	1	1	CO Case 2 Ringing only	CPE Case 1 Ring load	2	4 dB	--
8.7	Ringing with Cadencing test (with a splitter as a DUT)	56V	0	--	YES	Transient Peaks	CO	(2) 1	(0) 1	CO Case 3 cadenced ringing	CPE Case 1 Ring load	2	4 dB	**(X)** --
8.8	On-hook to Off-hook and back in the absence of ringing	56V	0 → 80 mA	Off-hook	--	--	CPE	(2) 1	(0) 1	CO Case 1 DC	CPE Case 3 on/offho	2	4 dB	**(X)** --
8.9	On-hook to Off-Hook ring-trip transition	56V	0 → 80 mA	Off-hook	YES	High Peaks	CO & CPE	(2) 1	(0) 1	CO Case 3 cadenced	CPE Case 3 on/offho	2	4 dB	**(X)** --
8.10	Data Rate Performance	56V	0 → 80 mA	--	--	--	--	(0) 1	(0) 1	DC	DC	2	4 dB	**(X)** --

CO POTS Models:
CO Case 1: DC battery + Voiceband AC impedance termination
CO Case 2: Ringing AC with DC battery (if needed); Continuous ringing
CO Case 3: alternating between Case 1 and 2

CPE POTS models:
Case 1: On-hook Z_{ring} model continuously (Section 7.2.2, Figure 7-3, or Section 7.3.2.1, Figure 7-13 with switch open)

Case 2: Off-hook model Z_{trip} model continuously (Section 7.3.2.1, Figure 7-13 with switch closed)
Case 3: Alternating on-hook to off-hook and back, Z_{ring}/Z_{trip} model (Section 7.3.2.1, Figure 7-13 with switch toggling)

(2) and (0): this marks the characterization of two baseline splitters

Ringing current: in Cadenced ringing transient current peaks can occur at the start and end of the ring burst; in Ring-Trip, high AC current peaks happen each 20-50 Hz period, due to a low-Ohmic phone.

The code violation (CRC) counts, used as pass/fail criteria for the test in this Section are made up of two parts:

1. CRC errors due to steady state background BER
2. CRC errors due to transients contained in transient events.

For the non-transient test cases the maximum allowed CRC count is limited by the background BER.

For transient test cases the maximum allowed CRC count is the sum of the CRCs allowed for the non-transient test case plus 1 CRC per 120 transient events.

The maximum background BER for testing triple play splitters while using profiles with 6 dB target margins and INPmin = 2 is required to be less than or equal to 1e-9 for both the downstream and upstream direction.

The maximum background BER for testing HSI splitters and in-line filters is 1 e-7.

The maximum allowed CRC count due to background BER can be expressed in function of mean time between error (MTBE), test duration and bitrate. The ratio of the test duration and MTBE is called 'Lambda'

MTBE is defined as

MTBE = 40/(BER*bitrate (bps)) for Interleaved profiles (Table 7-12/TR-100)

and

MTBE = 15/(BER*bitrate (bps)) for Fast profiles (Table 7-12/TR-100)

Lambda is defined as

Lambda = test duration(s)/MTBE(s)

For triple play splitter test the following applies:

MTBE = 40/(1e-9*bitrate (bps))

For test cases 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8 and 8.9:

Lambda = test duration(s)*1e-9*bitrate (bps)/40 (Formula 1a)

For test case 8.10

Lambda = test duration(s)*1e-7*bitrate(bps)/15 (Formula 1b)

For HSI splitter tests using an interleaved profile the following applies for test case 8.2 to 8.6:

Lambda = test duration(s)* 1e-9*bitrate (bps)/40 (Formula 2)

For HSI splitter tests using a Fast profile the following applies for test case 8.2 to 8.6:

Lambda = test duration(s)* 1e-7*bitrate (bps)/15 (Formula 3)

For In-line filter test using Interleaved profiles the following applies:

For test cases 8.2, 8.3 and 8.4:

Lambda = test duration(s)*1e-9*bitrate (bps)/40 (Formula 4a)

For test cases 8.5 and 8.6:

Lambda = test duration(s)*1e-7*bitrate (bps)/40 (Formula 4b)

For In-line filter test using Fast profiles the following applies for test case 8.2 to 8.6:

Lambda = test duration(s)* 1e-7*bitrate (bps)/15 (Formula 5)

The amount of CRCs expected within a specific measurement time can be calculated depending on the Lambda value using a Poisson distribution. Graphs of this distribution in function of Lambda are given in Appendix I. From this distribution function the number of allowed CRC count is derived.

The probability to detect the specified number of CRCs is done within a 99% confidence interval.

Table 8-7 lists the amount of CRCs expected versus a calculated Lambda value. If the calculated Lambda value falls between the numbers as specified table the next value in the table SHALL be used. This table is valid irrespective of the tested splitter type or if Interleaved or Fast profiles are used.

Table 8-7: Number of allowed CRCs versus Lambda

Lambda	Nr of CRC allowed
0.1	1
0.15	2
0.2	2
0.3	2
0.4	3
0.5	3
1	4
> 2	5

TEST		Expected system results for:														
		Triple-play splitters			HSI splitters						In-line filters					
		Interleaved			Interleaved			Fast			Interleaved			Fast		
Section 8.1.5		Formula 1a			Formula 2			Formula 3			Formula 4a			Formula 5		
Section	Test name	Required?	Downstream	Upstream	Required?	Downstream	Upstream	Required?	Downstream	Upstream	Required?	Downstream	Upstream	Required?	Downstream	Upstream
8.2	Lab calibration test without splitters	C	A	A	C	A	A	C	A	A	C	A	A	C	A	A
8.3	Continuous hook – State test using baseline splitters	C	A	A	C	A	A	C	A	A	C	A	A	C	A	A
		C	A	A	C	A	A	C	A	A	C	A	A	C	A	A
8.4	Continuous hook state test (with a splitter as a DUT)	D	A	A	D	A	A	D	A	A	D	A	A	D	A	A
8.5	Continuous ringing test with baseline splitters	C	A	A	C	A	A	C	A	A	Formula 4b			C	A	A
											C	A	A			
8.6	Continuous ringing test (with a splitter as a DUT)	D	A	A	D	A	A	D	A	A	D	A	A	D	A	A
8.7	Ringing with Cadencing test (with a splitter as a DUT)	D	F	G	D	B	B	E	B	B	D	B	B	E	B	B
8.8	On-hook to Off-hook and back in the absence of ringing	D	F	G	D	B	B	E	B	B	D	B	B	E	B	B
8.9	On-hook to Off-Hook ring-trip transition	D	F	G	D	B	B	E	B	B	D	B	B	E	B	B
Section 8.10		Fast			N/A			Fast			N/A			Fast		
8.10	Data Rate Performance	Formula 1b			N/A	N/A	N/A	D	H	H	N/A	N/A	N/A	E	H	H
		D	H	H												

PASS FAIL CRITERIA

A	Allowable CRCs per Table 8-7	B	Report CRCs	C	Baseline Test	D	Mandatory Test	E	Optional Test	F	1 CRC in 120 Transient Events + the Value per Table 8-7	G	24 CRCs in 120 Transient Events + the Value per Table 8-7	H	Allowable CRCs per Table 8-7 and no more than a 3% reduction in bitrate

Table 8-8: Expected System Results

NOTES

1. This is a Baseline Test – this is needed to evaluate the test setup and noise environment and to establish a bitrate calibration.

2. The Pass/Fail criteria for any given test are independent of whether or not Erasure Decoding is used.

Example calculation of maximum allowed CRC count for test case 8.2, executed for triple play on ADSL2plus loop 1:

The actual downstream data rate was 20600 kbps; actual upstream data rate was 944 kbps. The total number of measured CRC in step [9] was 1 CRC in Downstream and 0 CRC in Upstream. The measured time in step [9] was 121 seconds.

The ‘lambda’ for downstream is calculated according to Formula 1a:

Table 8-9: Example of CRC calculation

Downstream	Upstream
Lambda = test duration(s)*1e-9*bitrate (bps)/40 = 121s*1e-9*20.6e6/40 = 0.06	Lambda = test duration(s)*1e-9*bitrate (bps)/40 = 121s*1e-9*994e3/40 = 0.003
From Table 8-7: Lambda 0.06 -> 1 CRC allowed	From Table 8-7: Lambda 0.003 -> 1 CRC allowed
CRC measured DS = 1 -> PASS	CRC measured US = 0 -> PASS

8.2 Lab Calibration Test without Splitters

The purpose of this test is to verify the xDSL transmission, when all splitters are absent, is properly setup and configured. The measurement results from this are used to establish a baseline set of data, including the xDSL transceivers net data rate, noise margins, and transmit power levels. These measurement results SHALL be used in conjunction with results from the remaining tests within this Technical Report to study the effects caused by the splitter under test, while attempting to remove any potential bias of the loop type used, i.e. real loops or simulated loop models.

8.2.1 Goal

In this test an xDSL modem pair and the connection line at various lengths are characterized: the bitrate, noise margin, and transmit power level of the xDSL modem connection are measured. This test is intended as baseline test and to verify the xDSL modems and the loop, or loop simulator(s), in the test setup are properly setup and configured. Noise generators SHALL be connected at both ends of the line. However, there are no other components (i.e. no splitters, no CO POTS models and no CPE phone models).

This test SHOULD be run periodically to verify test setup is still correctly connected and configured, or to verify that there are no sudden sources of undesirable added noises or distortions. This test SHALL also be re-run anytime the xDSL transceivers are changed. In the lab environment the corrosion of a contact could cause issues, and certain unwanted RFI and EMI could also cause sudden degradation of the calibration set-up, especially when the balance of the set-up is jeopardized.

8.2.2 Configuration

The set-up contains two xDSL transceivers, the loop or loop models, and the xDSL noise generators. Splitters, the CO POTS models, and the CPE phone model are not yet included. The loop or the loop simulator models SHALL remain the same for the rest of the tests in the remaining part of this chapter.

.

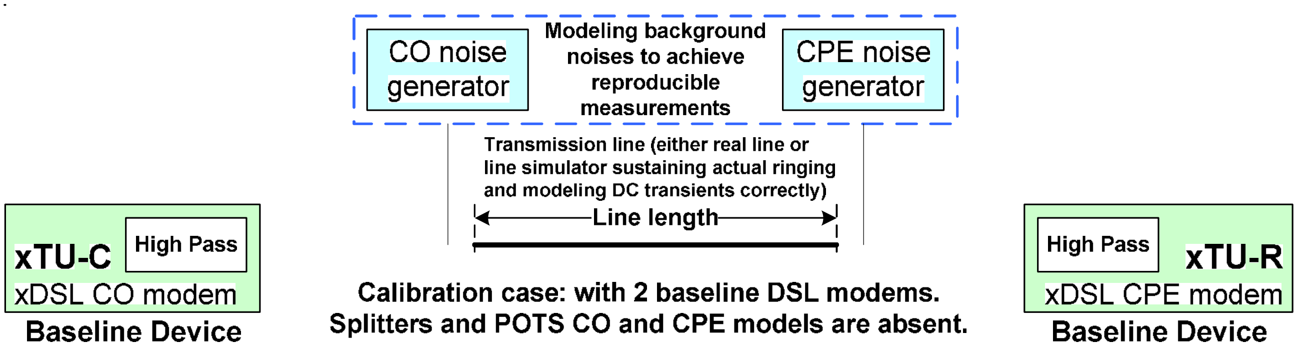


Figure 8-2: Calibration xDSL Baseline Test Procedure

8.2.3 Average Bit Rate Determination Test Procedure

The average bit rate determination test is a baseline measurement for the tests in Sections 8.3-8.9.

Table 8-10: Average Bit Rate determination Procedure

Method of Procedure	1. Sync the modem ten times for each test loop described in Table 8-1 (for VDSL2) and Table 8-2 (for ADSL2plus). 2. Disregard the entire measurement with the following: a. lowest upstream data rate b. highest upstream data rate c. lowest downstream data rate

	d. highest downstream data rate 3. Average the remaining modem data rates for downstream and upstream bit rates.

8.2.4 Test Procedure

Table 8-11: Calibration Test Procedure

Test Configuration	Refer to Section 8.2.2
Method of Procedure	1. Configure the test setup as described in 8.2.2 2. Configure the CPE and DSLAM according to the interleaved profile as defined in 8.1.3. (Fast profile follows afterwards.) 3. For the first test collect and record all data required in Sections 5.7, 5.8 and 5.9. 4. Connect the CPE and DSLAM with the first required test loop as defined in Section 8.1.2. 5. Force a new initialization and wait for modems to sync. 6. Wait for 2 minutes after initialization for bitswaps to settle. 7. Record the upstream and downstream noise margins 8. Collect the upstream and downstream data rates, noise margins, current CRC count, INP actual values and configured transmit power levels. 9. Wait 120 seconds 10. Record the measured time the number of reported CRC. The amount of measured CRC is the difference between the number recorded in this step 10 and the number recorded in step 8. Calculate Lambda according to the appropriate formula defined in 8.1.5. 11. Repeat steps 4 to 10 for all loops. 12. If applicable, repeat steps 2 to 11 with the CPE and DSLAM configured to the fast test profile.
Expected Result	NOTE: If a test point fails to achieve any of these expected results, the remainder of the tests SHALL not be performed on that test point. It is expected that for each loop tested, the CPE and DSLAM SHALL: 1. Establish a stable connection. 2. Initialize with a minimum noise margin of 4 dB. If the system under test is not able to achieve a minimum noise margin of 4 dB, the remainder of these tests SHALL not

	apply to that system (xDSL transceivers and loops). 3. Have the number of measured CRCs be less than or equal to the CRC value specified in Table 8-7 for the Lambda calculated under step 10.

NOTE: If the achieved bitrates in the test set-up is stable, with a variance of less than 1% from a previous averaged test, the test lab can reduce the complexity of the procedure by decreasing the number of steps in the averaging procedure, and by skipping the step in which the highest and lowest bitrates are disregarded.

8.2.5 Warning on the expected calibration results (Informative)

On short lines the margin announced by the xDSL transceivers baseline devices at initialization might be much larger than 6 dB combined with a maximal bitrate, but the margin when verified by increasing the level of the xDSL noise generators, might be different. It could indeed happen (and it is not unlikely) that the margin measured by increasing the external noise sources would be somewhat larger, or even substantially larger than what is announced by the xDSL transceiver.

This underestimation of the margin by the transceiver itself would happen when the strong signals are inducing some TX or RX non-linearities, which are equivalent to a noise that is larger than the AWGN (–140 dBm/Hz) that is injected. This would particularly happen when a TX part of a transceiver contains an irreducible noise level in its TX band, which (e.g. on short lines) is effectively much higher than the injected AWGN (at –140 dBm/Hz), and are not reduced over the line due to its shortness.

This would mean that the xDSL transceivers on short lines might report a measured margin ≥ 6 dB, but that the actual margin is much larger, due to TX and RX related inherent noises, induced inside the transceivers themselves. Better transceivers will have much less of these inherent RX or TX related noises, but that we cannot prevent transceivers to exhibit this kind of behavior, because we typically only require a performance in terms of a bitrate at a certain length with a minimum 4 dB margin.

The baseline measurements with a max bitrate and a margin larger or much larger than 6 dB are later used as a baseline. If splitters are used in conjunction with the xTU modem baseline devices, it is expected that the margins would be reduced.

8.3 Continuous hook-state Test using baseline splitters

The purpose of this test is establish a baseline set of data for the test setup under conditions including both CO and CPE splitters, and the POTS CO and CPE models. The baseline set of data for this test setup SHALL include the xDSL transceiver net data rates, noise margins, and transmit power levels. This baseline data set SHALL be compared to the data set of test 8.2, as described within the expected results.

8.3.1 Goal

In this test the xDSL transceivers, test loop, and baseline splitters are characterized: the bitrate and noise margin of the xDSL transceivers are measured in the static DC voltage and current situations.

This test is done as baseline test/check of the xDSL transceivers and the loop or loop simulator in the test set-up, and other components (CO POTS models and CPE phone models and the baseline splitters).

NOTE: the note under Section 8.2.1 is also applicable here.

8.3.2 Configuration

The set-up contains two xDSL transceivers, the loop or loop models, the xDSL noise generators, the baseline splitters, the CO POTS models, and the CPE phone models.

Care is used to minimize the unwanted noises, particularly unbalanced noise, injected by the POTS CO and CPE models.

On-hook state: the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Z_{trip} as defined in Section 7.3.2.1, with the switch open.

Off-hook state: the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Z_{trip} as defined in Section 7.3.2.1, with the switch closed.

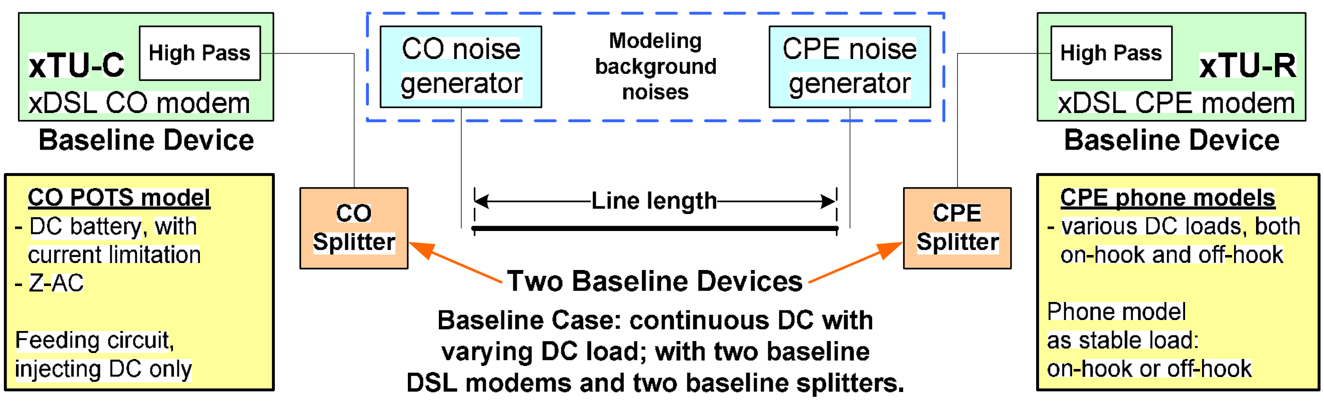


Figure 8-3: xDSL Baseline Test with splitters, without splitter as DUT

8.3.3 Test Procedure

Table 8-12: Baseline Test Procedure

Test Configuration	Refer to Section 8.3.2
Method of Procedure	**Part A (measurement of delta-SNR):** 1. Configure the test setup as described in 8.3.2 with injection of –140 dBm/Hz AWGN. 2. Configure the CPE and DSLAM according to the interleaved profile as defined in Section 8.1.3. (Fast profile

	follows afterwards.) 3. Connect the CPE and DSLAM to the CPE and CO baseline splitters respectively, leaving the CPE and CO splitter POTS ports open. 4. Connect the CPE and CO splitters with the first test loop defined in Section 8.1.2. 5. Force a new initialization and wait for modems to sync. Wait for 2 minutes after initialization for any bit-swaps to settle. 6. Collect and record the upstream and downstream noise margins, current CRC count, INP actual values, transmit power levels and data rates. 7. Wait 120 seconds 8. Record the measured time and the number of reported CRC. The amount of measured CRCs is the difference between the number recorded in this step 8 and the number recorded in step 6. Calculate Lambda according to the appropriate formula defined in 8.1.5. 9. Repeat steps 4 through 8 for each test loop defined in Section 8.1.2 10. If applicable, repeat steps 2 through 9 with the CPE and DSLAM configured to the fast test profile. **Part B (measurement of on-hook case):** 1. Configure the test setup as described in Section 8.3.2 with injection of –140 dBm/Hz AWGN. 2. Configure the CPE and DSLAM according to the interleaved profile as defined in Section 8.1.3. (Fast profile follows afterwards.) 3. Connect the CPE and DSLAM to the CPE and CO baseline splitters respectively. 4. Connect the POTS port of the CO splitter to the CO POTS model; see Section 7.1.1, (or equivalent Section 7.3.1.1 without ringing). 5. Connect the POTS ports of the CPE splitter to three on-hook CPE phone models; see Section 7.2.2(or Section 7.3.2.1 with switch open). 6. Connect the CPE and CO splitters with the first test loop defined in Section 8.1.2. 7. Force a new initialization and wait for modems to sync. Wait for 2 minutes after initialization for any bit-swaps to settle. 8. Collect and record the upstream and downstream noise margins, current CRC count, INP actual values, transmit

	power levels and data rates. 9. Wait 120 seconds 10. Record the measured time and the number of reported CRCs. The amount of measured CRCs is the difference between the number recorded in this step 10 and the number recorded in step 8. Calculate Lambda according to the appropriate formula defined in Section 8.1.5. 11. Repeat steps 6 through 10 for each additional test loop defined in Section 8.1.2. 12. If applicable, repeat steps 2 through 11 with the CPE and DSLAM configured to the fast test profile. **Part C (measurement of off-hook case):** 1. Configure the test setup as described in 8.3.2 with injection of –140 dBm/Hz AWGN. 2. Configure the CPE and DSLAM according to the interleaved profile as defined in Section 8.1.3. (Fast profile follows afterwards.) 3. Connect the CPE and DSLAM to the CPE and CO baseline splitters respectively. 4. Connect the POTS port of the CO splitter to the CO POTS model; see Section 7.1.1 (or equivalent Section 7.3.1.1 without ringing). 5. Connect the POTS port of the CPE splitter to two on-hook CPE phone models, see Section 7.2.2, (or section 7.3.2.1 with switch open).and one off-hook CPE model, see Section 7.3.2.1 with switch closed. 6. Connect the CPE and CO splitters with the first test loop defined in Section 8.1.2. 7. Force a new initialization and wait for modems to sync. Wait for 2 minutes after initialization for any bit-swaps to settle. 8. Collect and record the upstream and downstream noise margins, current CRC count, INP actual values, transmit power levels and data rates. 9. Wait 120 seconds. 10. Record the measured time and the number of reported CRCs. The amount of measured CRCs is the difference between the number recorded in this step 10 and the number recorded in step 8. Calculate Lambda according to the appropriate formula defined in Section 8.1.5. 11. Repeat steps 6 through 10 for each additional test loop defined in Section 8.1.2. 12. If applicable, repeat steps 2 through 11 with the CPE and

	DSLAM configured to the fast test profile.
Expected Result	**Part A (measurement of delta-SNR):** NOTE: If a test point fails to achieve any of these expected results, the remainder of the tests SHALL not be performed on that test point. It is expected that for each loop tested, the xDSL transceivers SHALL: 1. Establish a stable connection. 2. Achieve a data rate not more than 3% below what was recorded for the same test loop in Section 8.2.3. 3. Initialize with a minimum noise margin of at least 4 dB as collected in step 6. 4. Not exhibit continued coding violations or loss of synchronization. 5. Have the number of measured CRCs be less than or equal to the CRC value specified in Table 8-7 for the Lambda calculated under step 8. **Part B (measurement of on-hook case) and** **Part C (measurement of off-hook case):** It is expected that for each loop tested, the xDSL transceivers SHALL: 1. Establish a stable connection. 2. Achieve a data rate not more than 3% below what was recorded for the same test loop in Section 8.2.3. 3. Initialize with a minimum noise margin of at least 4 dB as collected in step 8. 4. Not exhibit continued coding violations or loss of synchronization. 5. Have the number of measured CRCs SHALL be less than or equal to the CRC value specified in Table 8-7 for the Lambda calculated under step 10.

8.4 Continuous hook-state test (with a Splitter as the DUT)

8.4.1 Goal

In this test one splitter is added as a device under test to an xDSL transmission environment, a second splitter, of opposite type SHALL also be required to allow for the injection and/or extraction of the POTS signals. Opposite type SHALL mean that if the DUT is a CPE splitter, the opposite type is a CO splitter. The purpose of this test is to check, that the presence of a splitter as DUT, will not affect the xDSL transmission in steady state. We are checking mainly for stationary distortion degrading xDSL transmission. This is done with and without DC current flowing through the loop under test.

Indeed, the splitter might cause a continuous xDSL transmission degradation (e.g. by adding continuous distortion, e.g. by clipping or limited dynamic range, both in on-hook and off-hook states).

8.4.2 Configuration

Refer to Section 8.3.2, with the only difference being the addition (replacement) of one splitter as the DUT.

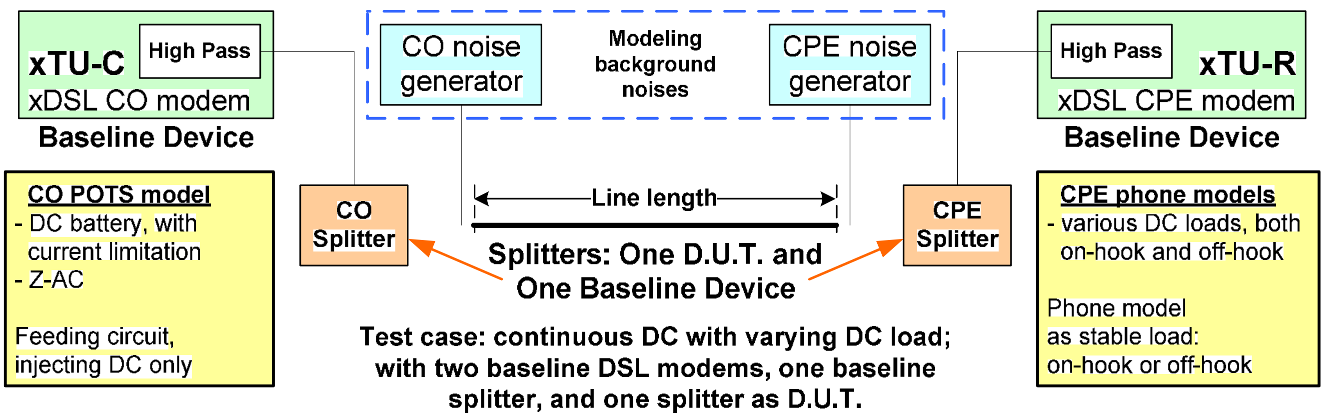


Figure 8-4: Continuous hook-state Test setup

8.4.3 Test Procedure

Table 8-13: Continuous hook-state Test Procedure

Test Configuration	Refer to Section 8.4.2, identical to 8.3.2, except for the presence of one splitter DUT.
Method of Procedure	1. Replace one of the splitters (CO or CPE) with the splitter considered the DUT. 2. Repeat Test 8.3 entirely (Part A, Part B and Part C).
Expected Result	See expected results from Test 8.3.

8.5 Continuous ringing test using baseline splitters

The purpose of this test is to check that the presence of a continuous ringing signal will not adversely affect the xDSL transmission, including only the baseline splitters.

In this test, under the continuous ringing signal condition, the number of code violation errors within the xDSL transceiver system SHOULD be consistent with Table 8-7.

This is primarily a test for the baseline devices, the ringing generator, and the AC CPE POTS model.

This test is only a baseline check, and MAY only need to be executed occasionally, or anytime a change in the baseline devices is made, to validate that:

- The xDSL modems can withstand the high voltages contained in the ringing signal;
- The baseline splitters and loop models can sustain the high voltages and medium currents within the ringing signal (see Section 5.4);
- The ringing generator does not inject noises (differential or common mode), such that the achieved bitrate or noise margin is not significantly negatively impacted by the continuous ringing signal.

NOTE: Although on real telephone lines there is no continuous ringing signal, this test is included as a baseline check. Indeed, under cadenced ringing the start and stop edges of the ringing might contain noises that cause errors within the xDSL transmission system. To discriminate between errors and degradation caused by intermodulation between ringing and xDSL signals and the errors caused by the start and stop of a cadenced ringing, the ringing is applied continuously during this test.

8.5.1 Goal

This test is occasionally done as an absolute test of the components of the test set-up and the ring generator.

In this test the xDSL transceivers and the test environment are tested to check the capability of the xDSL transceivers to withstand continuous ringing signals. In this test it is also possible to check if there are issues caused by the actual test loops, the loop simulators, the baseline splitters or the ring generators, which could cause xDSL transmission degradation, even when the splitters as devices under tests are absent. Possible effects of degradation under ringing caused by the test set-up can be characterized.

NOTE: Overload and distortion can exist in certain line simulators (see Section 5.4).

This test SHOULD be run periodically to verify test setup is still correctly connected and configured, or to verify that there are no sudden sources of undesirable added noises or distortions. This test SHALL also be re-run anytime the xDSL transceivers are changed. In the lab environment the corrosion of a contact could cause issues, and certain unwanted RFI and EMI could also cause sudden degradation of the calibration set-up, especially when the balance of the set-up is jeopardized.

8.5.2 Configuration

The xDSL transceivers, the ring generator, loop model, baseline splitters and CPE ringer models are connected as shown below. The DUT splitter is not yet included within the test setup.

The ringing signal is continuously injected via the POTS port of a CO splitter of baseline quality into the loop under test. The CO POTS models are defined within Section 7.3.1.1. One of the ringing injection methods from the table below SHALL be used for the entire suite of tests.

Table 8-14: Ringing Injection Types

	Balanced Injection	Unbalanced Injection
Serial	Figure 7-6	Figure 7-7
Parallel	Figure 7-4	Figure 7-5

The loop is terminated with a CPE splitter of baseline quality in the on-hook state. That is, the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Z_{trip} as defined in Section 7.3.2.1, with the switch open.

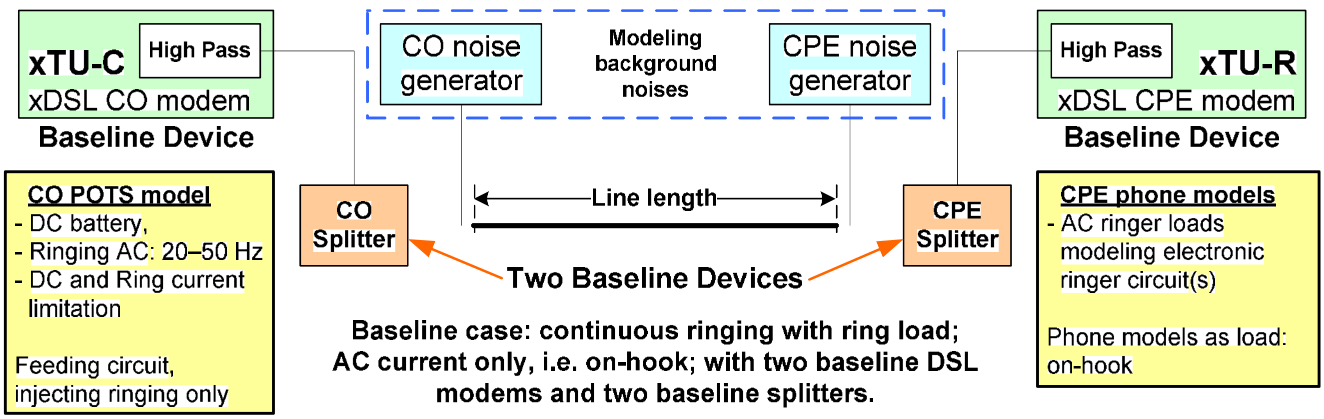


Figure 8-5: Continuous ringing baseline case

8.5.3 Test Procedure

Table 8-15: Continuous ringing Test Procedure

Test Configuration	Refer to Section 8.5.2
Method of Procedure	1. Configure the test setup as described in 8.5.2 with injection of –140 dBm/Hz AWGN. 2. Configure the CPE and DSLAM according to the interleaved profile as defined in Section 8.1.3. (Fast profile follows afterwards.) 3. Connect the CPE and DSLAM to the CPE and CO baseline splitters respectively. 4. Connect the POTS port of the CO splitter to the CO POTS model of Section 7.3.1.1 (ring generator and injection circuitry not injecting ringing yet). 5. Connect the POTS port of the CPE splitter to three CPE electronic ringer models; see Section 7.2.2, (or 7.3.2.1 with switch open). 6. Connect the CPE and CO splitters with the first test loop defined in Section 8.1.2. 7. Force a new initialization and wait for modems to sync. Wait for 2 minutes after initialization for any bit-swaps to settle. 8. Inject a continuous ringing signal into the CO splitter. 9. After 5 seconds, collect and record the upstream and downstream noise margins, INP actual values, transmit power levels, current CRC count, and data rates.

	10. Wait 120 seconds. 11. Record the measured time and the number of reported CRCs. The amount of measured CRCs is the difference between the number recorded in this step 11 and the number recorded in step 9. Calculate Lambda according to the appropriate formula defined in Section 8.1.5. 12. Repeat steps 6 through 11 for each additional test loop defined in Section 8.1.2. 13. If applicable, repeat steps 2 through 12 with the CPE and DSLAM configured to the fast test profile.
Expected Result	NOTE: If a test point fails to achieve any of these expected results, the remainder of the tests SHALL not be performed on that test point. It is expected that for each loop tested, the CPE and DSLAM SHALL: 1. Establish a stable connection. 2. Achieve a data rate not more than 3% below what was recorded for the same test loop in Section 8.2.3. 3. Initialize with a noise margin of at least 4 dB as collected in step 9. 4. Do not exhibit continued coding violations, loss of synchronization, or inability to train. 5. Have the number of measured CRCs be less than or equal to the CRC value specified in Table 8-7 for the Lambda calculated under step 11.

8.6 Continuous ringing test (with a splitter as DUT)

The purpose of this test is to check that the presence of continuous ringing will not adversely affect the xDSL transmission system, when splitters as devices under test are added to an xDSL transmission environment. This test verifies the splitter, as DUT, does not create intermodulation products between the xDSL signals and the ringing signal. If such intermodulation products exist, this will result in an unacceptable drop of the xDSL transceiver's noise margin(s), or even an inability for the xDSL transceivers to maintain synchronization, while the continuous ringing signal is present.

NOTE: the note under Section 8.5 explains the usefulness to test under continuous ringing; it is also applicable here.

8.6.1 Goal

When continuous ringing is applied in the presence of splitters, we determine if a splitter as DUT, causes (additional) continuous xDSL transmission degradation, primarily by causing intermodulation between the xDSL signals and the ringing signals. For example, an amplitude modulation of the xDSL signal could be caused by non-linear behavior of the components in the splitter, under either the voltage or the current caused by the continuous ringing signals.

8.6.2 Configuration

Connect the xDSL transceivers, a ring generator, loop model, splitters (one baseline, and one as the device under test) as shown below. The splitter device under test is located at either the CO or CPE side of the loop.

The ringing signal is continuously injected via the POTS port of a CO splitter of baseline quality into the loop under test. The CO POTS models are defined within Section 7.1.1.1. One of the ringing injection methods from the table below SHALL be used for the entire suite of tests.

Table 8-16: Ringing Injection Types

	Balanced Injection	Unbalanced Injection
Serial	Figure 7-6	Figure 7-7
Parallel	Figure 7-4	Figure 7-5

The loop is terminated with a CPE splitter of baseline quality in the on-hook state. That is, the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Z_{trip} as defined in Section 7.3.2.1, with the switch open.

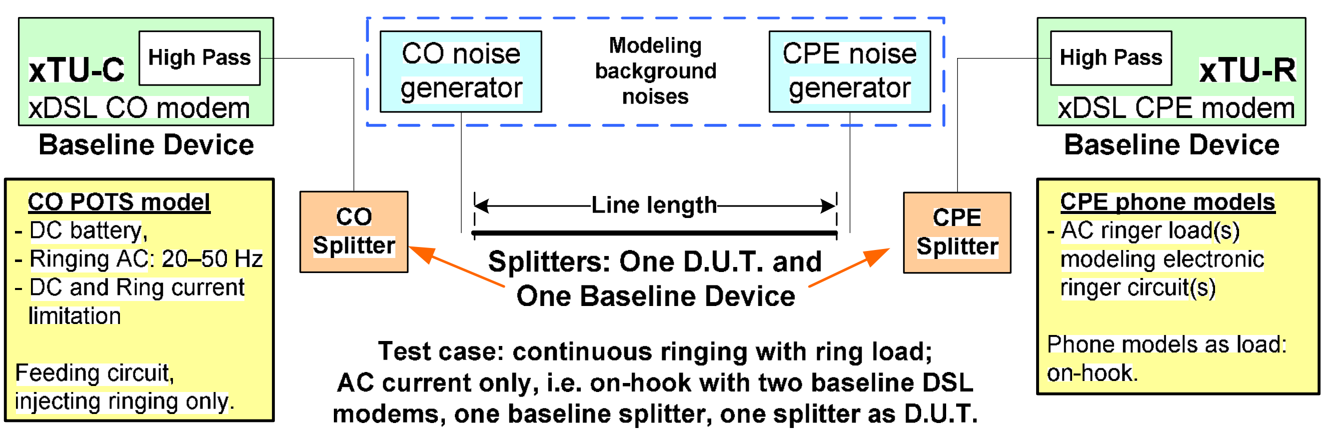


Figure 8-6: Continuous ringing test case

8.6.3 Test Procedure

Table 8-17: Continuous ringing Test Procedure

Test Configuration	Refer to Section 8.6.2.
Method of Procedure	1. Replace one of the splitters (CO or CPE) with the splitter considered the DUT. 2. Repeat Test 8.5.
Expected Result	See expected results from Test 8.5.

8.7 Ringing with Cadencing Test (with a splitter as DUT)

This test MAY also be performed on the baseline splitters.

8.7.1 Goal

The purpose of this test is to measure how the presence of cadenced ringing might affect the xDSL transmission, when one splitter is present as the DUT in an xDSL transmission environment.

When cadenced ringing is applied, the xDSL transmission system is checked for degradation caused by the periodic ringing transients. This degradation is measured as a margin reduction and/or as observable coding violation errors.

8.7.2 Configuration

This test requires xDSL transceivers, a ring generator, loop models, and splitters that passed the continuous ringing test in Sections 8.5 and 8.6.

The CO POTS models are defined within Section 7.1.1.1. Use the ringing injection types as described in Table 8-14. The cadenced ring generator SHALL be xDSL-unfriendly, as defined within Section 7.3.1.2.3. The cadence speed of the ringing injection MAY be increased to reduce the test time. The minimum cadence period is defined within Section 7.3.1.2.1. Each cadenced ringing event SHALL be defined as the combination of the ringing and non-ringing periods. Each cadenced ringing event contains two transient events, i.e. one start of ringing and one stop of ringing. The total number of transient events for this test is 240.

The loop is terminated with a CPE splitter of baseline quality in the on-hook state. That is, the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Z_{trip} as defined in Section 7.3.2.1, with the switch open.

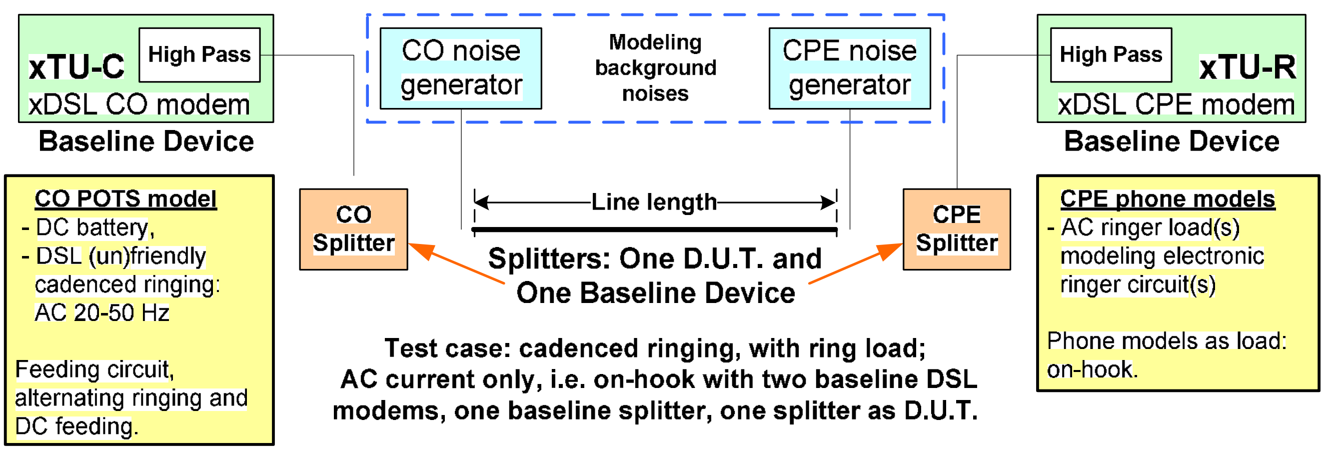


Figure 8-7: Cadenced ringing test case

8.7.3 Test Procedure

Table 8-18: Cadenced ringing Test Procedure

Test Configuration	Refer to Section 8.7.2
Method of Procedure	1. Configure the test setup as described in 8.7.2 with injection of –140 dBm/Hz AWGN. 2. Configure the CPE and DSLAM according to the interleaved profile as defined in Section 8.1.3. (Fast profile follows afterwards.)

	3. Connect the POTS port of the CPE splitter to three electronic ringer models, see Section 7.2.2, (or 7.3.2.1 but with the switch continuously open). 4. Connect the POTS port of the CO splitter to the AC/DC CO POTS model, Section 7.3.1.1, capable to inject ringing, but in the DC "battery feeding" state first. 5. Connect the CPE splitter and CO splitter with the first required test loop. 6. Force a new initialization and wait for modems to sync. Wait for 2 minutes after initialization for bitswaps to settle. 7. Collect and record the upstream and downstream noise margins, net data rates, INP actual values, transmit power levels, and current CRC count. 8. Inject an xDSL unfriendly ringing signal into the CO splitter 9. Wait for a full cadenced ringing period. 10. Remove the ringing using a sliding phase incremented with 6 degrees for each subsequent removal. 11. Increase the phase angle used to inject the ringing in step 8 by 6 degrees for each subsequent injection. 12. Repeat steps 8 to 11, 120 times. 13. Record the measured time and the number of reported CRCs. The number of measured CRCs is the difference between the number recorded in this step 13 and the number recorded in step 7. Calculate Lambda according to the appropriate formula defined in 8.1.5. 14. Repeat steps 4 through 13 with all additional loops. 15. If applicable, repeat steps 2 through 14 with the CPE and DSLAM configured to the fast test profile.
Expected Result	It is expected that for each loop tested, the CPE and DSLAM SHALL: 1. Establish a stable connection. 2. Achieve a data rate not more than 3% below what was recorded for the same test loop in Section 8.2.3. 3. Initialize with a minimum noise margin of at least of 4 dB as collected in step 7. 4. Following the injection of the cadenced ringing, not exhibit continued coding violations when configured in interleaved mode. 5. Not undergo a loss of synchronization. 6. For Pass/Fail criteria values refer to Table 8-8.

8.8 On to Off-hook transition and back in absence of ringing

This test as well MAY also be performed on the baseline splitters.

8.8.1 Goal

The purpose of this test is to measure how off-hook and on-hook events affect the xDSL transmission system, when the DUT splitter is present in the xDSL transmission environment.

The off-hook event at the CPE side happens for an out-going call, or for in-coming call when the phone is picked up during ringing AC silence. The on-hook happens at the end of the phone call.

8.8.2 Configuration

This test requires the xDSL transceivers, the CO POTS battery feeding model, loop models and splitters, as defined in Section 7.3.1.1

On-hook state: the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Z_{trip} as defined in Section 7.3.2.1, with the switch open.

Off-hook state: the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Z_{trip} as defined in Section 7.3.2.1, with the switch closed.

The on-hook to off-hook transition is, by definition, xDSL-unfriendly.

The cadence of the hook transitions MAY be enhanced to reduce the test time. The minimum on-hook and off-hook periods are 500 ms each. The transition from the on-hook state to off-hook state and back to on-hook is considered to be one hook-cycle event. Each hook-cycle event contains two transient events, i.e. one off-hook and one on-hook. The total number of transient events for this test is 240, 120 off-hook and 120 on-hook transitions.

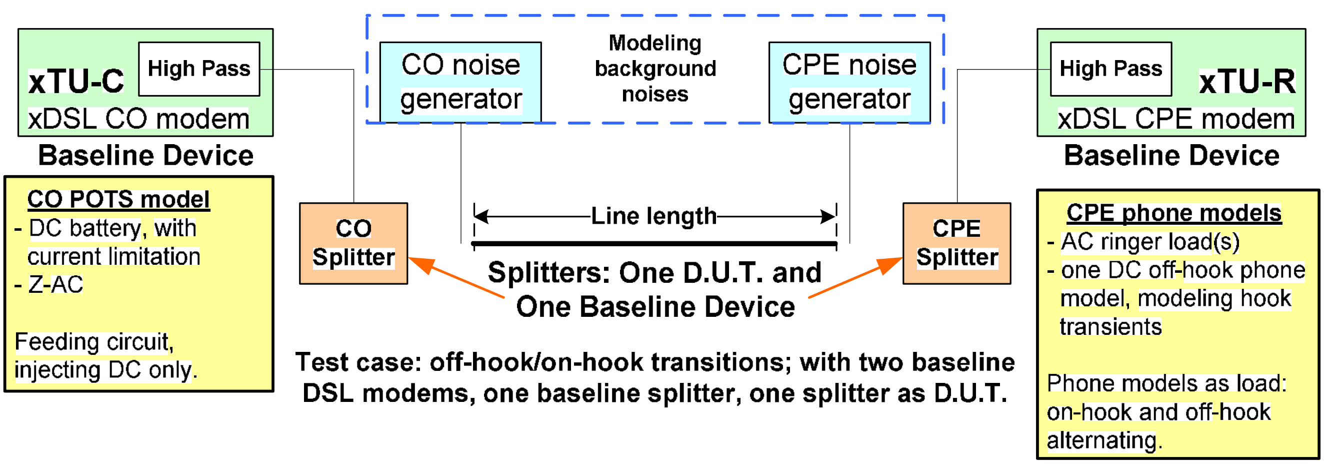


Figure 8-8: On/Off-Hook Test setup

8.8.3 Test Procedure

Table 8-19: On/Off-Hook Test Procedure

Test Configuration	Refer to Section 8.8.2
Method of Procedure	1. Configure the test setup as described in 8.8.2 with injection

	of –140 dBm/Hz AWGN. 2. Configure the CPE and DSLAM according to the interleaved profile as defined in 8.1.3. (Fast profile follows afterwards.) 3. Connect the POTS port of the CPE splitter as described in the Configuration of 8.8.2. 4. Connect the POTS port of the CO splitter to the AC/DC CO POTS model, see Section 7.3.1.1 in the continuous DC "battery feeding" state without ringing. 5. Connect the CPE splitter and CO splitter with the first required test loop. 6. Force a new initialization and wait for modems to sync. Wait for 2 minutes after initialization for bitswaps to settle. 7. Collect and record the upstream and downstream noise margins, net data rates, INP actual values, transmit power levels, and current CRC count. 8. Apply 120 hook-cycle events with the one CPE phone model, at a rate of not more than 60 hook-cycle events per minute, by closing and opening the switch in one model of Section 7.3.2.1. 9. Record the measured time and the number of reported CRCs. The amount of measured CRCs is the difference between the number recorded in step this step 9 and the number recorded in step 7. Calculate Lambda according to the appropriate formula defined in 8.1.5. 10. Repeat steps 4 through 9 with all additional loops. 11. If applicable, repeat steps 2 through 10 with the CPE and DSLAM configured to the fast test profile.
Expected Result	It is expected that for each loop tested, the CPE and DSLAM SHALL: 1. Establish a stable connection. 2. Achieve a data rate not more than 3% below what was recorded for the same test loop in Section 8.2.3. 3. Initialize with a minimum noise margin of 4 dB as collected in step 7. 4. Following the hook transitions, not exhibit continued coding violations when configured in interleaved mode. 5. Following (or during) the hook transitions, not undergo a loss of synchronization. 6. For Pass/Fail criteria values refer to Table 8-8.

8.9 On-hook to Off-hook ring-trip transition

This test MAY also be performed on the baseline splitters.

8.9.1 Goal

This test models the off-hook transition when an in-coming call is picked up, while the AC ringing signal is present on the loop.

The purpose of this test is to measure how multiple ring-trip events during ringing signal might affect the xDSL transmission, when elements of the system are present as the DUT in an xDSL transmission environment.

8.9.2 Configuration

This test requires the use of xDSL transceivers, a CO POTS battery feeding plus ringing model, CPE electronic ringer models, lines or line models and splitters. The ringing injection SHALL be xDSL-friendly to avoid causing additional coding violation errors. Use the ringing injection types as described in Table 8-14. Section 7.3.1 describes the addition and removal of the ringing signals to the line. The sequence of starting ringing, off-hook transition, stop of ringing and on-hook transition is considered to be one ring-trip event see Figure 7-13. Each ring-trip event contains two transient events at the CPE side, i.e. one off-hook and one on-hook and two transitions at the CO side injecting and removing the ringing. The total number of transient events for this test is 240 of which the 120 off-hook transitions will be more harmful to the xDSL transmission than the on-hook events. The 240 CO side ringing injecting and removing transients SHOULD be as DSL-friendly as possible.

On-hook state: the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Z_{trip} as defined in Section 7.3.2.1, with the switch open.

Off-hook state: the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Z_{trip} as defined in Section 7.3.2.1, with the switch closed.

The on-hook to off-hook phone model is by definition of xDSL-unfriendly type.

The POTS port of the CO side splitter is connected to the CO POTS model defined within Section 7.3.1.1.

The cadence of the ringing injection and the related off-hook transitions MAY be enhanced to reduce the test time, as defined within Section 7.3.2.3.

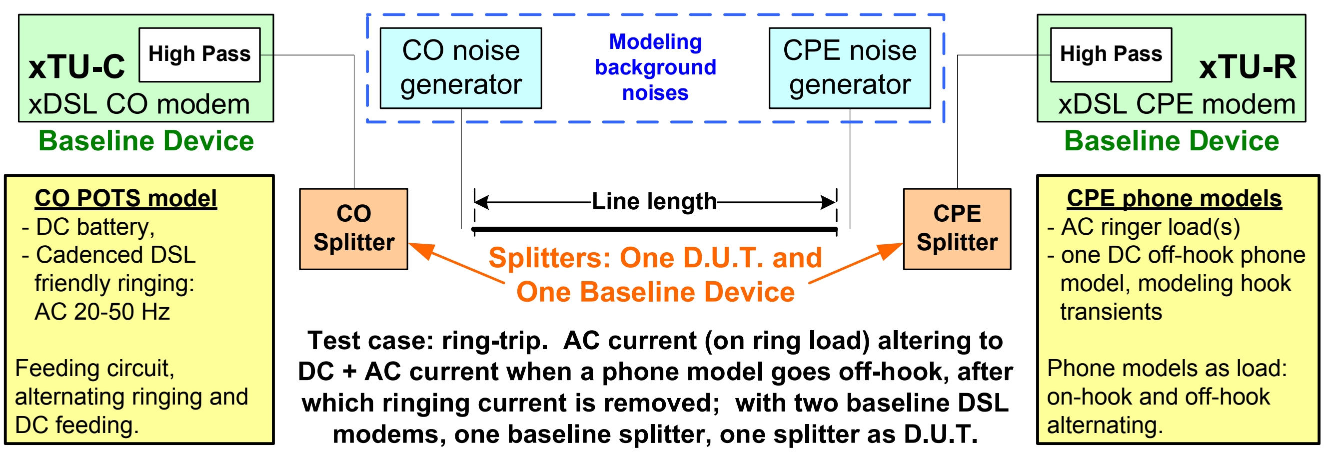


Figure 8-9: Ring trip setup

8.9.3 Test Procedure

Table 8-20: Ring Trip Test Procedure

Test Configuration	Refer to Section 8.9.2

Method of Procedure	1. Configure the test setup as described in Section 8.9.2 with injection of –140 dBm/Hz AWGN. 2. Configure the CPE and DSLAM according to the interleaved profile as defined in Section 8.1.3. (Fast profile follows afterwards.) 3. Connect the CPE and DSLAM to the CPE and CO splitters respectively. Note, one splitter SHALL be considered the DUT, while the other splitter SHALL be the same device used in Section 8.3, the test report SHALL note the specific make, model, and version of all splitters and transceivers used to complete the testing and clearly indicate which splitter is considered the DUT. 4. Connect the POTS port of the CO splitter to the CO POTS model, see Section 7.3.1.1 (ring generator and injector circuitry) at first in DC "battery feeding" state without ringing. 5. Connect the POTS port of the CPE splitter as described in the Configuration of 8.9.2. 6. Connect the CPE and CO splitters with the first test loop defined in Section 8.1.2. 7. Force a new initialization and wait for modems to sync. Wait for 2 minutes after initialization for any bit-swaps to settle. 8. Collect and record the upstream and downstream net data rate, current CRC count, noise margins, INP actual values, and transmit power levels. 9. Inject the ringing signal, as defined in Section 7.3.2.3 into the CO splitter, with xDSL-friendly injection. 10. Cause one CPE phone model to transition to the off-hook state. To ensure that all phases are tested use the ring trip modeling described in Section 7.3.2.3 by using sliding phase and 6 degrees of phase increment for each subsequent off-hook event. 11. Ensure the ringing signal is removed from the line at the next zero crossing of the ringing signal (xDSL friendly ringing). 12. Cause the single CPE phone model in off-hook to transition back to the on-hook state, which is not phase sensitive, because ringing is no longer present. 13. Repeat steps 9 through 12 for a total of 120 times. 14. Record the measured time and the number of reported CRCs. The amount of measured CRCs is the difference between the number recorded in this step 14 and the number recorded in step 8. Calculate Lambda according to the appropriate formula defined in Section 8.1.5. 15. Repeat steps 6 through 14 for each additional test loop

	defined in Section 8.1.2. 16. If applicable, repeat steps 2 through 15 with the CPE and DSLAM configured to the fast test profile.
Expected Result	It is expected that for each loop tested, the CPE and DSLAM SHALL: 1. Establish a stable connection. 2. Achieve a data rate not more than 3% below what was recorded for the same test loop in Section 8.2.3. 3. Initialize with a minimum noise margin of 4 dB. 4. Not exhibit a loss of synchronization as a result of the ringing signals and on/off hook transitions. 5. For Pass/Fail criteria values refer to Table 8-8.

8.10 Data Rate Performance

8.10.1 Goal

This test SHALL only apply to systems using VDSL2 transceivers. A pass means successful completion of the IMD test and the CRC test contained in the Section below. These tests ensure that the splitter has adequate IMD performance by measuring bit rate performance. This is an implicit measurement of IMD. Much effort has been spent in ATIS and ETSI trying to develop an explicit IMD test setup. This proved to be very difficult and thus it is proposed to do a delta rate test.

8.10.2 Configuration

These tests are done on a DSLAM (VTU-O) and CPE (VTU-R) combination without splitters and then repeated after including the network and remote splitters in the DSLAM and CPE setup. The splitter tests SHALL be done in the on-hook and off-hook conditions with the appropriate DC bias and POTS current. The average bit rate determination procedure described in section 8.10.3 SHALL be performed first before the rate/reach IMD tests.

On-hook state: the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Ztrip as defined in Section 7.3.2.1, with the switch open.

Off-hook state: the POTS port of the CPE side splitter is terminated by two electronic ringer models as defined in Section 7.2.2 and one Ztrip as defined in Section 7.3.2.1, with the switch closed.

The POTS port of the CO side splitter is connected to the CO POTS model defined within Section 7.3.1.1.

To ensure IMD performance over each VDSL2 profile the test configurations in Table 8-1 SHALL be used:

Table 8-21: Test Configurations for Rate/Reach IMD Tests

Profile	North America Loop 26 AWG (or equivalent)	European Loop 0.4 mm (or equivalent)	VTU-O Noise (dBm/Hz)	VTU-R Noise (dBm/Hz)	Maximum bitrate reduction (%)	Record Data On:
8d	1800 ft	550 m	-140	-140	3	upstream & downstream
17a	1000 ft	300 m	-140	-140	3	upstream & downstream
30a	1000 ft	300 m	-140	-140	3	upstream & downstream

The following test procedure SHALL be followed:

Test 1 – Baseline VTU-C and VTU-R without splitters– Test Connection Between DSLAM and CPE

Test 2 – Baseline plus Network and Remote Splitters – On-hook condition - Test Connection Between DSLAM and CPE including both Network and Remote Splitters with -48VDC bias voltage and no current to simulate on-hook phone condition.

Test 3 - Baseline plus Network and Remote Splitters – Off-hook condition - Test Connection Between DSLAM and CPE including both Network and Remote Splitters with current to simulate off-hook phone condition.

.

8.10.3 Test Procedure

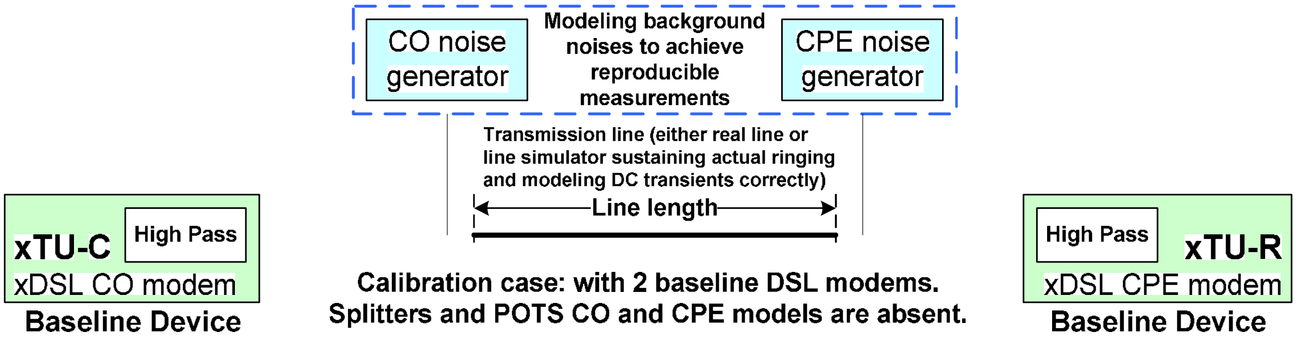


Figure 8-10: Bit Rate Performance Calibration

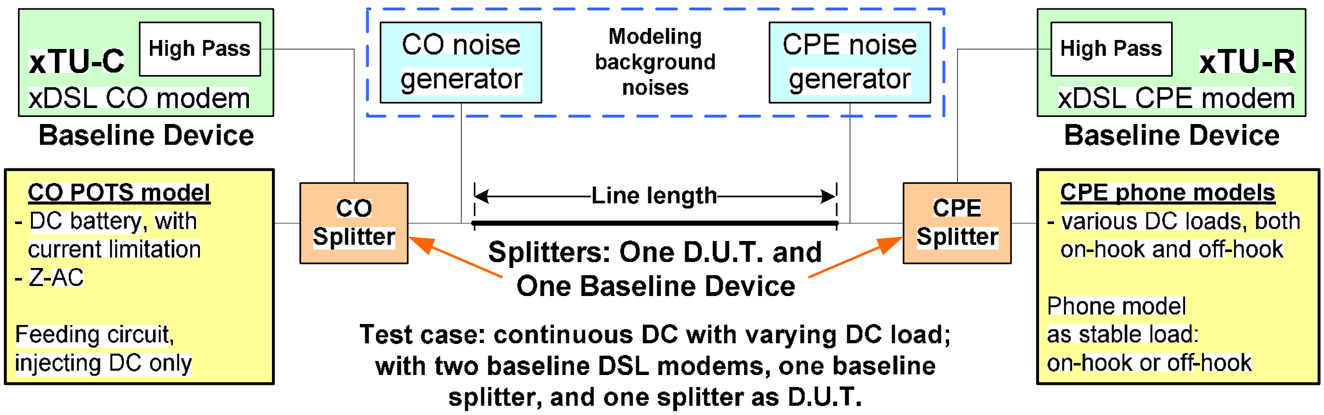


Figure 8-11: Bit Rate Performance Test

Table 8-22: Average Bit Rate determination Procedure used for Test 1, 2 & 3

Test Configuration	Refer to Figure 8-10 and Figure 8-11.
Method of Procedure	1. Sync the modem ten times for each loop. Profile 8d, 17a and 30a each have Tests 1- 3 for a total of nine tests. 2. Disregard the entire measurement with the following: a. lowest upstream data rate b. highest upstream data rate c. lowest downstream data rate d. highest downstream data rate 3. Average the remaining modem data rates for downstream and upstream. Record this number for later use.

If the achieved bitrates in the test set-up are stable, with a variance of less than 1% from a previous averaged test, the test lab MAY reduce the complexity of the procedure by decreasing the number of steps in the averaging procedure, and by skipping the step in which the highest and lowest bitrates are disregarded.

Table 8-23: Rate/Reach IMD Average Test Procedure

Test Configuration	Refer to Figure 8-10 and Figure 8-11.
Method of Procedure	1. Configure the test setup as described in 8.2.2 (Figure 8-10) for test1 or 8.3.2 (Figure 8-11) for test2 and test3 with the appropriate profile, loop and injected noise as described in Table 8-21. 2. Configure the CPE and DSLAM according to the fast test profile as defined in 8.1.3. The DSLAM is provisioned to allow the port to sync at the highest rate possible on the line, given the required margin. 3. Connect the CPE and DSLAM with the first required test loop. 4. Determine the average rate according to the procedure in Table 8-22 for test1. 5. Determine the average rate according to the procedure in Table 8-22 for test2. 6. Determine the average rate according to the procedure in Table 8-22 for test3. 7. Repeat until all VDSL2 profiles (8d, 17a and 30a) are complete.
Expected Result	1. Establish a stable connection. 2. Initialize with a minimum noise margin of 4 dB. 3. The average maximum bit rate reduction SHALL be no worse than 3% for VDSL2 in fast mode between test 1 compared with test 2 and 3 for both upstream and downstream net data rates.

<u>If the IMD average test is passed, continue with the IMD CRC test procedure. Otherwise this Section is a fail.</u>

Table 8-24: Rate/Reach IMD CRC Test Procedure

Test Configuration	Refer to Figure 8-10 and Figure 8-11.
Method of Procedure	1. Configure the test setup as described in Section 8.2.2 with the appropriate profile, loop and injected noise as described in Table 8-21. 2. Configure the CPE and DSLAM according to the fast test profile as defined in 8.1.3. The DSLAM is provisioned to allow the port to sync at the highest rate possible on the line, given the required margin.

	3. Connect the CPE and DSLAM with the first required test loop 4. Force a new initialization and wait for modems to sync. 5. If the net data rate is within 5% of the average rate found in the absence of a DUT with the procedure of Table 8-13, continue with step 5. If not, reinitialize the modem until the net data rate is within the 5% range. 6. Wait for 2 minutes after initialization for bitswaps to settle. 7. Record the upstream and downstream net data rates and number of reported CRCs at both ends. 8. Wait for 120 seconds. 9. Record the measured time and the number of reported CRCs. The number of measured CRCs is the difference between the number recorded in step 9 and the number recorded in step 7. 10. Calculate Lambda according to the appropriate formula defined in 8.1.5. Record the CRC value specified in Table 8-7 for the calculated Lambda. 11. Repeat steps 1 through 10 with splitters added for Test 2 as specified in 8.3.2 (on-hook condition). 12. Repeat steps 1 through 10 for Test 3 as specified in 8.4.2 (off-hook condition).
Expected Result	It is expected that for each tested profile and loop the CPE, DSLAM and splitters (when used) SHALL: 4. Establish a stable connection. 5. Have the number of measured CRCs less than or equal to the CRC value calculated in step 8. 6. Initialize with a minimum noise margin of 4 dB. Note: Any significant difference in data rate could be attributed to a poor stopband or some other issues in the splitter and/or IMD.

Appendix I: Poisson Probability Distribution

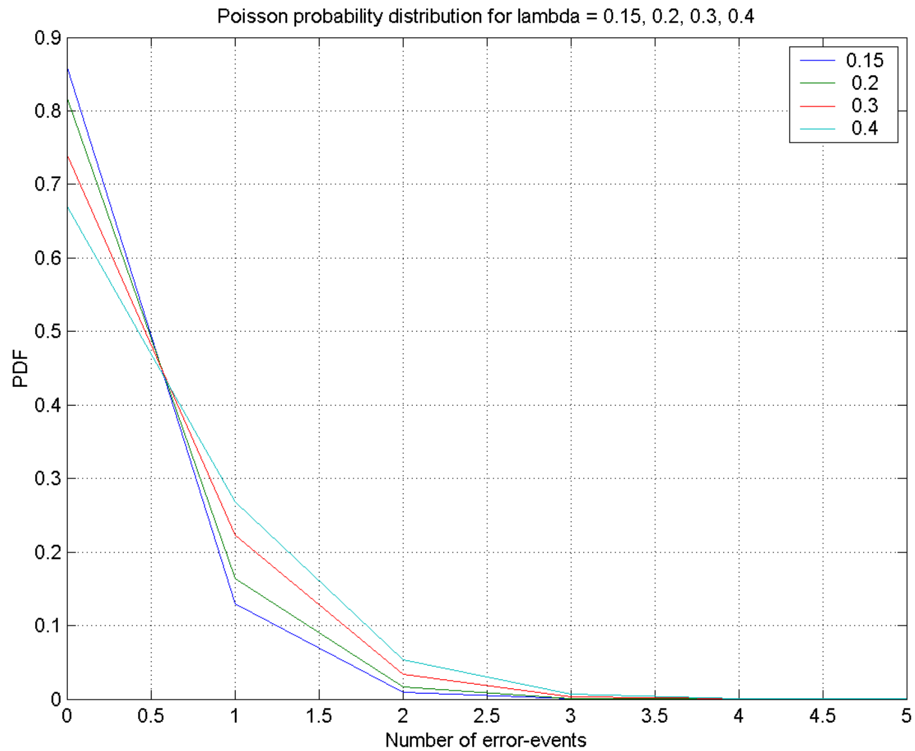


Figure I-1: Poisson probability distribution for Lambda 0.15, 0.2, 0.3 and 0.5

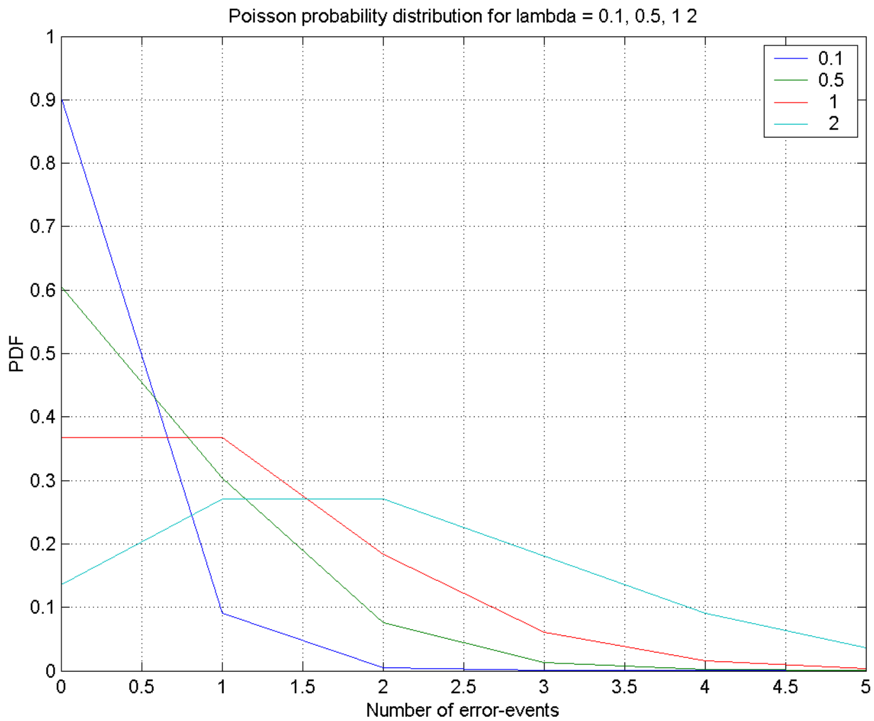


Figure I-2: Poisson probability distribution for Lambda 0.1, 0.5, 1 and 2

Appendix II: Bibliography

Some referenced documents were created by ITU. Other references are specifically for Europe and were created by ETSI.

[B1] ETSI TBR 038: "Public Switched Telephone Network (PSTN); Attachment requirements for a terminal equipment incorporating an analogue handset function capable of supporting the justified case service when connected to the analogue interface of the PSTN in Europe".

[B2] ETSI TR 102 139: "Compatibility of POTS terminal equipment with xDSL systems".

[B3] ITU-T Recommendation O.42: "Equipment to measure non-linear distortion using the 4-tone intermodulation method".

[B4] ETSI TBR 021: "Terminal Equipment (TE); Attachment requirements for pan-European approval for connection to the analogue Public Switched Telephone Networks (PSTNs) of TE (excluding TE supporting the voice telephony service) in which network addressing, if provided, is by means of Dual Tone Multi Frequency (DTMF) signaling".

[B5] ETSI TR 101 728: "Access and Terminals (AT); Study for the specification of low pass filter Section of POTS/ADSL splitters".

[B6] ITU-T Recommendation O.41: "Psophometer for use on telephone-type circuits".

[B7] ITU-T Recommendation O.9: "Measuring arrangements to assess the degree of unbalance about earth".

[B8] ETSI ES 201 970: "Access and Terminals (AT); Public Switched Telephone Network (PSTN); Harmonized specification of physical and electrical characteristics at a 2-wire analogue presented Network Termination Point (NTP)".

[B9] ETSI EN 300 659 (all parts): "Access and Terminals (AT); Analogue access to the Public Switched Telephone Network (PSTN); Subscriber line protocol over the local loop for display (and related) services".

[B10] ETSI ES 200 778 (all parts): "Access and Terminals (AT); Analogue access to the Public Switched Telephone Network (PSTN); Protocol over the local loop for display and related services; Terminal equipment requirements".

[B11] ETSI EN 300 001: "Attachments to the Public Switched Telephone Network (PSTN); General technical requirements for equipment connected to an analogue subscriber interface in the PSTN".

[B12] ETSI ES 201 729: "Public Switched Telephone Network (PSTN); 2-wire analogue voiceband switched interfaces; Timed break recall (register recall); Specific requirements for terminals".

[B13] ETSI ES 201 187: "2-wire analogue voiceband interfaces; Loop Disconnect (LD) dialling specific requirements".

[B14] ETSI TR 101 953-1-1: "Access and Terminals (AT); Unified and Generic Testing Methods for European Specific DSL splitters; Part 1: ADSL splitters for European deployment; Sub-part 1: Specification of Testing methods for Low Pass part of ADSL/POTS splitters".

[B15] ETSI TR 101 953-2-1: "Access network xDSL transmission filters; Part 2: VDSL splitters for European deployment; Sub-part 1: Specification of Testing methods for low pass part of VDSL/POTS splitters".

[B16] ETSI TS 101 952-1-2: "Access network xDSL transmission filters; Part 1: ADSL splitters for European deployment; Sub-part 2: Specification of the high pass part of ADSL/POTS splitters".

[B17] ETSI TS 101 952-2-2: "Access network xDSL transmission filters; Part 2: VDSL splitters for European deployment; Sub-part 2: Specification of the high pass part of VDSL/POTS splitters for use at the Local Exchange (LE) and the user side near the Network Termination Point (NTP)".

End of Broadband Forum Technical Report TR-127