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**Access, Terminals, Transmission and Multiplexing (ATTM);
Access network xDSL splitters for European deployment;
Part 3: Generic specification of static distributed filters for
xDSL over POTS**

Reference

RTS/ATTM-06019

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

The present document is part 3 of a multi-part deliverable covering Access network xDSL transmission filters, as identified below:

Part 1: "Generic specification of xDSL over POTS splitters";

Part 2: "Generic specification of xDSL over ISDN splitters and xDSL universal splitters";

Part 3: "Generic specification of static distributed filters for xDSL over POTS";

Part 4: "Additional specifications for dynamic distributed filters for xDSL over POTS (under study)".

NOTE 1: The present document is derived from previous specifications of distributed filters for ADSL over POTS. Before the publication of the 3 (or 4) parts as described above, the TS 101 952 was composed of 2 parts, which discriminated between ADSL and VDSL, with several subparts. For reasons of simplicity the TS is now restructured as a set of only 3 (potentially 4) documents, intended for both ADSL and VDSL when applicable. The older structure of the documents is explained in the informative [Annex B](#).

NOTE 2: Useful information on splitter tests also applicable to distributed filters may be found in TR 101 953-1-1 [i.3] and TR 101 953-2-1 [i.5]. These documents are linked to the previous versions of the splitter specifications. [i.3] and [i.5] e.g. describe the combination of the AC testing conditions of the test set-ups with the DC conditions controlled via feeding and loading bridges. If there is a discrepancy between the present document and the TR 101 953 series of documents [i.3] to [i.8], the present document prevails.

NOTE 3: The use of distributed filters is not recommended for VDSL, but it is not excluded. For this reason the parts 3 and 4 refer to distributed filters for xDSL and not just for ADSL.

NOTE 4: In the present document we introduce three classes of filters: basic, standard and enhanced. The reasoning behind this approach is clarified in [Clause 6.1.1](#).

NOTE 5: When multiple distributed filters are installed in parallel the quality of the POTS band signals tend to degrade proportionally to the number of filters placed at the customer's premises. This effect is explained in [Clause C.1](#). This degradation effect is worse if multiple distributed filters of basic quality are used, or filters that only fulfil the previous published requirement (TS 101 952-1-5 (V1.2.1) [i.17]). In that case also the DSL signals can potentially be degraded. The latter is further addressed in the informative [Annex B](#).

The present document is fully in line with initiative "eEurope 2002 - An Information Society For All", under "The contribution of European standardization to the eEurope Initiative, A rolling Action Plan" especially under the key objective of a cheaper, faster and secure Internet.

Introduction

Remarks and limitations of the present document.

The present document covers all xDSL system variants, such as ADSL1, ADSL2, ADSL2plus, VDSL1 and VDSL2. It is applicable at only at the Terminal Equipment (TE) (i.e. user) side of the line. There is no equivalent of the distributed filter at the CO side. The CO side central splitter requirements for xDSL over POTS splitters are in TS 101 952-1 [11].

The present document is derived from previous specifications of distributed filters for ADSL over POTS, and it corrects the errors of the older versions as explained in [Annex B](#). It now contains measurements and requirements for the combined effect when multiple distributed filters are deployed in parallel.

A number of limitations and remarks of the present document should be listed:

- 1) Originally the present document was limited to distributed filters for ADSL. It is now extended to cover also distributed filters for VDSL. In the ITU-T documents a warning note is recommending not to use distributed filters for VDSL. E.g. see note 7 of section 5.4 of G.993.2 [i.13]). However, if distributed filters are used in VDSL2 scenarios to achieve a faster and cheaper deployment of service, operators should realize that this could prevent VDSL to attain its maximum theoretical transmission performances, and that ERM/EMC problems of the VDSL could worsen.
- 2) The present document covering xDSL over POTS distributed filters was gained from the experience with passive and static DSL splitters, the original state of the art for this application. Therefore, the requirements in the present document are primarily intended for passive and static distributed filters at the TE side only.
- 3) There are other classes of filters possible, besides passive and static splitters. Such active and/or dynamic filters are composed of other elements than passive components. Active/dynamic splitters require different and additional requirements and test methods to be specified. Indeed, the dynamic behaviour of the splitter could allow the requirements to differ depending on the state of the line, e.g. requiring isolation, attenuation, rejection and insertion loss values to be adapted to the on-hook and the off-hook state of the line. The full specification of requirements for active/dynamic splitter is F.F.S. An introduction to this is in the informative [Annex K](#). Additional requirements might be in TS 101 952-4 [i.14] (under study).
- 4) Distributed filters have less stringent isolation requirements than central splitters. The non-linearity of some telephone sets may then cause audible back-ground noise in the POTS band, disturbing the phone conversation and potentially even reducing the DSL capacity, particularly when the phone is picked-up.
- 5) Besides testing static requirements according to the present document, there exists a dynamic testing methodology, compiled by the broadband forum, in TR-127 [i.15]. The TR-127 [i.15] methodology for POTS splitters and filters is now published. A tutorial text on TR-127 [i.15] is given in informative [Annex H](#). The TR-127 [i.15] test methodology is considered a useful method of assessing overall filter performance and could be carried out complementarily to the present specification. For certain properties the TR-127 [i.15] methodology is sometimes the only feasible method at an acceptable complexity. Indeed, TR-127 [i.15] may prove that a filter works correctly in a worst case xDSL test environment, including POTS DC and ringing signals. The use of the TR-127 [i.15] methodology for this purpose is suggested for certain clauses in the present document, but out of scope.
- 6) The use of Option A and B for defining Return Loss is kept in the present document in exactly the same way as it is used for POTS splitters.

1 Scope

The present document specifies requirements and test methods for "xDSL over POTS" distributed filters. These filters are at the user side of the local loop in the customer premise.

- Unlike the splitters (sometimes called central splitters to distinguish them from distributed filters) described in TS 101 952-1 [11] and TS 101 952-2 [12], the distributed filters do not contain a high pass part. Therefore, only the low pass part is tested.
- Furthermore, the central splitters mentioned above are used as a single device at each end of the line. Distributed filters are often not used as a single device, but as multiple parallel devices. This aspect, which was not tested in a previous version of the present document (see note 5 of the [Foreword](#) and the informative [Annex B](#)), is now tested also.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at <http://docbox.etsi.org/Reference>.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

- [1] 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".
- [2] ITU-T Recommendation O.42: "Equipment to measure non-linear distortion using the 4-tone intermodulation method".
- [3] ETSI ES 203 021-3: "Access and Terminals (AT); Harmonized basic attachment requirements for Terminals for connection to analogue interfaces of the Telephone Networks; Update of the technical contents of TBR 021, EN 301 437, TBR 015, TBR 017; Part 3: Basic Interworking with the Public Telephone Networks".

NOTE: ETSI TBR 021 has been made historical.

- [4] ITU-T Recommendation O.41: "Psophometer for use on telephone-type circuits".
- [5] ITU-T Recommendation O.9: "Measuring arrangements to assess the degree of unbalance about earth".
- [6] 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)".
- [7] ETSI EN 300 659-1: "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; Part 1: On-hook data transmission".
- [8] ETSI ES 200 778-1: "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; Part 1: On-hook data transmission".

- [9] ETSI ES 201 729: "Public Switched Telephone Network (PSTN); 2-wire analogue voice band switched interfaces; Timed break recall (register recall); Specific requirements for terminals".
- [10] ETSI ES 201 187: "2-wire analogue voice band interfaces; Loop Disconnect (LD) dialling specific requirements".
- [11] ETSI TS 101 952-1: "Access network xDSL splitters for European deployment; Part 1: Generic specification of xDSL over POTS splitters".
- [12] ETSI TS 101 952-2: "Access, Terminals, Transmission and Multiplexing (ATTM); Access network xDSL splitters for European deployment; Part 2: Generic specification of xDSL over ISDN splitters and xDSL universal splitters".

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] ETSI TR 102 139: "Compatibility of POTS terminal equipment with xDSL systems".
- [i.2] ETSI TR 101 728: "Access and Terminals (AT); Study for the specification of low pass filter section of POTS/ADSL splitters".
- [i.3] 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".
- [i.4] ETSI TR 101 953-1-2: "Access network xDSL transmission filters; Part 1: ADSL splitters for European deployment; Sub-part 2: Testing methods for High Pass part of ADSL/POTS splitters".
- [i.5] 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".
- [i.6] ETSI TR 101 953-2-2: "Access network xDSL transmission filters; Part 2: VDSL splitters for European deployment; Sub-part 2: Specification of Testing methods for high pass part of VDSL/POTS splitters".
- [i.7] ETSI TR 101 953-1-3: "Access network xDSL transmission filters; Part 1: ADSL splitters for European deployment; Sub-part 3: Testing methods for ADSL/ISDN splitters".
- [i.8] ETSI TR 101 953-2-3: "Access network xDSL transmission filters; Part 2: VDSL splitters for European deployment; Sub-part 3: Specification of Testing methods for VDSL/ISDN splitters".
- [i.9] ITU-T Recommendation G.992.1: "Asymmetric Digital Subscriber Line (ADSL) transceivers".
- [i.10] ITU-T Recommendation G.992.3: "Asymmetric Digital Subscriber Line transceivers 2 (ADSL2)".
- [i.11] ITU-T Recommendation G.992.5: "Asymmetric Digital Subscriber Line (ADSL) transceivers - Extended bandwidth ADSL2 (ADSL2plus)".
- [i.12] ITU-T Recommendation G.993.1: "Very high speed Digital Subscriber Line transceivers (VDSL)".
- [i.13] ITU-T Recommendation G.993.2: "Very high speed Digital Subscriber Line transceivers 2 (VDSL2)".
- [i.14] ETSI TS 101 952-4: "Access, Terminals, Transmission and Multiplexing (ATTM); Access network xDSL splitters for European deployment; Part 4: Additional specifications for dynamic distributed filters for xDLS over POTS (under study)".

NOTE: This Document is under construction.

[i.15] Broadband Forum TR-127: "Dynamic Testing of Splitters and In-Line Filters with xDSL Transceivers", Issue 1.

NOTE: This document can be downloaded at <http://www.broadband-forum.org/technical/download/TR-127.pdf>.

[i.16] ETSI TS 101 952-1-5 (V1.1.1): "Access network xDSL transmission filters; Part 1: ADSL splitters for European deployment; Sub-part 5: Specification for ADSL over POTS distributed filters".

NOTE: This document is part of the **earliest version** of the distributed filter specifications. See comments in [Annex B](#).

[i.17] ETSI TS 101 952-1-5 (V.1.2.1): "Access network xDSL transmission filters; Part 1: ADSL splitters for European deployment; Sub-part 5: Specification for ADSL over POTS distributed filters".

NOTE: This document is part of the most recent **previous version** of the POTS splitter specs. See comments in [Annex B](#).

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

A-wire and B-wire: wires in the 2-wire local loop connection provided from the exchange to the NTP

active splitter or active distributed filter: splitter or filter containing some active components

balun: transformer, used to convert balanced into unbalanced signals or vice-versa

central splitter: splitter that is used to isolate xDSL frequencies from POTS frequencies at a single point (often called NTP) at the customer's premises; (occasionally it is also called a master splitter)

distributed filter: low pass filter that is added in series with each of the parallel connected POTS TE

NOTE: Each of these parallel connected filters (in the in-house cabling) is known as a distributed filter. These filters are also known as In-line filters or microfilters.

dynamic splitter or dynamic distributed filter: splitter or filter changing its transfer behaviour dynamically, e.g. based on the state of the POTS connection

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

master splitter: See central splitter.

Network Termination Point (NTP): demarcation point between the access pair and the in-house wiring, where often the central splitter is placed

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: See ES 203 021-3 [3]. 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 central splitter or the distributed filter when **one** terminal 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: See ES 203 021-3 [3]. In the case where multiple TEs are present at the customer end of the loop, then the TEs is considered to be on-hook from the perspective of testing the central splitter or the distributed filter only when **all** terminals are on-hook.

passive splitter or passive distributed filter: splitter or filter containing exclusively passive components

sidetone: 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 less than approximately 5 ms, making it indistinguishable from the original utterance

static distributed filter: distributed filter not intended to change its transfer function based on the state of the POTS connection

NOTE: These filters are also known as single state distributed filters.

static splitter: splitter not intended to change its transfer function based on the state of the POTS connection

NOTE: These splitters are also known as single state splitters.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Att_{DB}	Attenuation in the xDSL Band (LINE port to xDSL port, or reversed)
C_{DSL}	The capacitor C part of the Z_{DSL}
f_H	highest of the used frequencies in the xDSL Band
f_L	lowest of the used frequencies in the xDSL Band
f_{M1}	intermediate frequency, at the edge between US or US0 and the DS band for xDSL
f_{Max}	maximum frequency above xDSL band for measurements
IL_{DBOffH}	Insertion Loss xDSL Band Off-Hook
IL_{DBOnH}	Insertion Loss (Isolation) xDSL Band On-Hook
$IL_{MaxOffH}$	Maximal Insertion Loss Off-Hook (in the POTS band)
IL_{MaxOnH}	Maximal Insertion Loss On-Hook (Low Impedance, in the POTS band)
IL_{Meter}	Insertion Loss for Metering (Off-Hook)
IL_{PBOnH}	Insertion Loss POTS Pass Band On-Hook
IL_{TBOffH}	Insertion Loss Transition Band, only measured in Off-Hook
$IL_{VarOffH}$	Maximal Insertion Loss Variation Off-Hook (in the POTS band)
IL_{VarOnH}	Maximal Insertion Loss Variation On-Hook (Low Impedance, in the POTS band)
LCL	Longitudinal Conversion Loss
$LCL_{LINEport}$	LCL at the LINE port
$LCL_{POTSport}$	LCL at the POTS port
LCTL	Longitudinal Conversion Transfer Loss
$LCTL_{POTSstoLINE}$	LCTL from POTS port to LINE port
L_{DSL}	The inductance L part of the Z_{DSL}
N_{DB}	Noise in the xDSL band
N_{PB}	Noise in the POTS band (psophometric)
R_{AtoB}	DC resistance between A and B wire
R_{DC}	DC Resistance of a splitter or filter for POTS current
R_{DSL}	The resistive R part of the Z_{DSL} ($R_{DSL} \equiv Z_{RefDSL}$)
R_{FEED}	Variable DC feed resistor in Figure 3
R_{LOAD}	Variable DC load resistor in Figure 4
RL_{PBOffH}	Return Loss POTS Pass Band Off-Hook
S_{DSL}	Switch to connect xDSL impedance Z_{DSL} to the test set-up
S_{PAR}	Switch to connect N-1 filters to the test set-up, in parallel with the main filter DUT
UaE_{PB}	Unbalance about Earth in the POTS Band
V_{RD}	V Ring-Drop
Z_{AC}	Generic name for the AC POTS impedance models
Z_{DSL}	Impedance model of the input filter of a particular xDSL

Z_{InRing}	The input impedance of the splitter or filter at the ringing frequencies
Z_{LOAD}	Generic name of the load impedance, e.g. in the Figures in Clause 5.4.6 on RL test set-up
Z_{ON}	Generic name of the POTS ON-hook impedance
Z_{OnHI}	Impedance modelling POTS On-hook with High Impedance
Z_{OnHo}	Impedance modelling multiple parallel on-hook phones
Z_{OnLI}	Impedance modelling POTS On-hook with Low Impedance
Z_{R}	European harmonized complex reference POTS impedance
Z_{Ref}	Generic name of Reference POTS impedance in RL formula in Clause 5.4.5
Z_{RefDSL}	Nominal Reference Design Impedance of xDSL ($Z_{\text{RefDSL}} \equiv R_{\text{DSL}}$)
Z_{RHF}	Complex POTS impedance, extending Z_{R} to higher frequencies, see TR 102 139 [i.1]
Z_{Ring}	Impedance modelling the load represented by ringer circuits
Z_{SL}	Impedance Z Short Loop, modelling a short line terminated on 600 Ω

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AC	Alternating Current
ADSL	Asymmetric Digital Subscriber Line
ADSL1	Asymmetric Digital Subscriber Line 1
NOTE:	ADSL limited to 1,1 MHz; specified in ITU Recommendation G.992.1 [i.9].
ADSL2	Asymmetric Digital Subscriber Line 2
NOTE:	Revised in ITU-T Recommendation G.992.3 [i.10].
ADSL2plus	ADSL2 "Plus"
NOTE:	ADSL extended to 2,2 MHz; specified in ITU-T Recommendation G.992.5 [i.11].
CLI	Calling Line Identification
CLIP	Calling Line Identification Presentation
CMRR	Common Mode Rejection Ratio
CO	Central Office (\equiv Local Exchange \equiv LE)
CM	Common mode
CRC	Cycle Redundancy Check
DC	Direct Current
DS	Downstream, i.e. LE to TE side
DSL	Digital Subscriber Line
DTMF	Dual Tone Multi-Frequency
DUT	Device Under Test
e.m.f.	Electro-Magnetic Force
F.F.S.	For Further Study
FSK	Frequency Shift Keying
HPF	High Pass Filter
IL	Insertion Loss
ISDN	Integrated Services Digital Network
IMD	Inter Modulation Distortion
ITU	International Telecommunication Union
LE	Local Exchange (\equiv Central Office \equiv CO)
N.A.	Not Applicable
NTP	Network Termination Point
POTS	Plain Old Telephone Service (used throughout instead of PSTN)
PSD	Power Spectral Density
PSTN	Public Switched Telephone Network (replaced throughout the text by POTS)
RL	Return Loss
RMS	Root Mean Square
SDSL	Symmetric DSL
SLIC	Subscriber Line Interface Circuit

TE	Terminal Equipment (e.g. Telephone, Fax, voice band modem etc.)
THD	Total Harmonic Distortion
UaE	Unbalance about Earth
US	Upstream, i.e. TE to LE side
US0	Upstream "0" band, the lowest VDSL upstream band

NOTE: Specified in ITU-T Recommendations [i.12] and [i.13].

VDSL	Very high speed Digital Subscriber Line
VDSL1	Very high speed Digital Subscriber Line 1

NOTE: Specified in ITU-T Recommendation G.993.1 [i.12].

VDSL2	Very high speed Digital Subscriber Line 2
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NOTE: Specified in ITU-T Recommendation G.993.2 [i.13].

xDSL	ADSL or VDSL
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NOTE: This abbreviation stands for ADSL or VDSL and its use this way is strictly limited to the present group of documents; e.g. HDSL, SDSL and SHDSL are not covered.

4 General functional description of xDSL over POTS distributed filters

A tutorial on the transmission and separation of POTS and xDSL signals is in [Annex I](#).

The main purpose of the xDSL over POTS distributed filter 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 distributed filter also serves to protect POTS terminal equipment from interference due to ingress from xDSL signals. Equally it protects the xDSL transmission from transients generated primarily during POTS signalling (dialling, ringing, ring trip, etc.), and it must also prevent 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).

Information on various implementations of xDSL over POTS splitters and filters is given in TR 101 728 [i.2]. Insertion of a distributed filter in existing POTS lines shall only have a low impact on the performance of the POTS service.

The differences between a distributed filter and a central splitter (the latter being specified in TS 101 952-1 [11]) are defined more by the location and the performance of the filter rather than the function. Central splitters are designed to be located at a central position, at the demarcation point of the customer premise, and provide separation of POTS and xDSL signals at a single location. Distributed filters on the other hand are placed in series with each piece of POTS terminal equipment (or in series with a few pieces only). Thus distributed filters are two port devices, as seen in Figure 1 (central splitters have three ports). Hence, when voice grade equipment is protected by distributed filters the xDSL signals are delivered over the entire customer premise wiring. Multiple filters are only used at the customer's premises, as shown in Figure 1, in which there is a single central splitter at the CO side of the line.

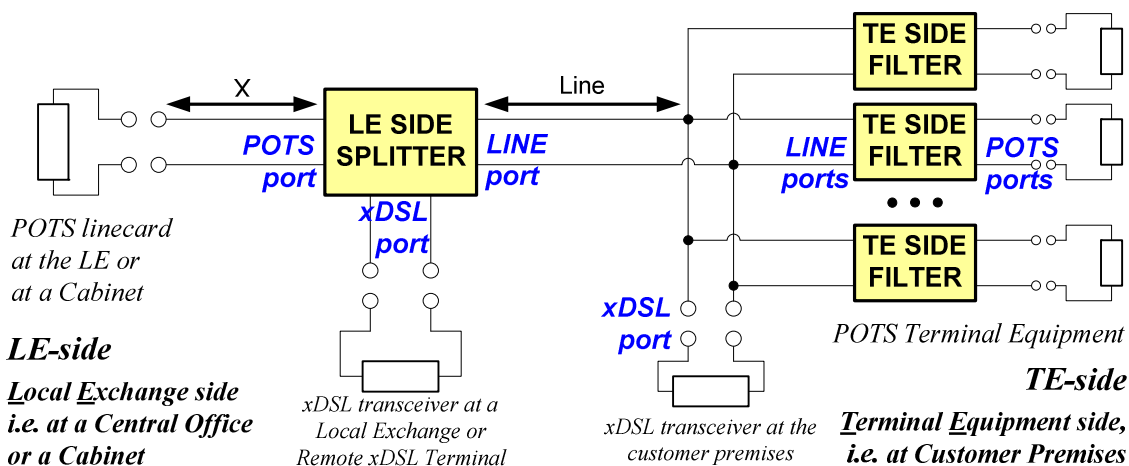
NOTE: On the quality and performance of distributed filters. The quality of the POTS and the xDSL services may be negatively affected by the number of distributed filters installed. The extent of this effect is expected to be proportional to the number of distributed filters installed. See also [clause C.1](#).

Furthermore, the distributed filters are intended to be a convenient solution that can be installed by the user. The performance of both the POTS and xDSL services is often reduced by using distributed filters instead of a central splitter. The central splitter almost always ensures a higher input impedance for the xDSL frequency band at the line port than the distributed filters in parallel. Moreover, in the xDSL band the central splitter isolates the in-house wiring from the external line and the xDSL system and will almost certainly reduce electromagnetic interference.

It is recognized that dynamic distributed filters can give improved performance over static filters. Additional requirements for dynamic filters will be covered in TS 101 952-4 [i.14]. The TR-127 [i.15] of the Broadband forum will provide additional methodology to test the functionality of the dynamic filters. A tutorial text on TR-127 [i.15] is given in the informative [Annex H](#).

4.1 Functional diagram

The functional diagram for distributed filters is given in Figure 1. The filters specified by the present document are intended to be connected only in series with the POTS TE. Operation is not specified for serial stacking (i.e. connecting one distributed filter in series with another distributed filter). The stacking of distributed filters is not recommended.



NOTE: For a Local Exchange xDSL deployment, the length "X" in this Figure will typically be far less than 1 km. For a remote xDSL terminal deployment, the length "X" can be up to several kilometres.

Figure 1: Functional diagram of the DSL splitter configuration with distributed filters

The transfer function between the POTS port and LINE port (and vice-versa) of each TE side filter in Figure 1 is that of a low pass filter, as shown in Figure 2. The LINE port and the xDSL port coincide for a distributed filter, i.e. there is no optional highpass as is allowed for POTS central splitters, or no mandatory DC blocking capacitors, as is the case for ISDN splitters, or universal splitters, as explained in TS 101 952-1 [11] and TS 101 952-2 [12].

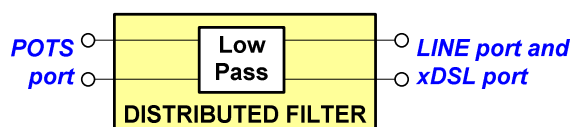


Figure 2: Structure of the xDSL distributed filter

4.2 High pass filter

For central splitters for xDSL over POTS an optional series high pass filter can be located in the splitter unit. Similarly ISDN splitters contain a high pass filter.

This is not the case for distributed filters, which never contain a high pass function. For distributed filters the xDSL transceiver contains the DC blocking function and an additional high pass functionality.

5 Circuit definitions, testing conditions and methods

5.1 DC and ringing testing conditions

5.1.1 Polarity independence

The distributed filter shall conform to all the applicable requirements of the present document for both polarities of the DC line feeding voltage and for both directions of the DC line current provided by the local exchange.

5.1.2 DC feeding conditions (on-hook/off-hook)

The electrical requirements in the present document can be classified as follows (see also under definitions):

- On-hook requirements, when all POTS terminals are in the on-hook state.
- Off-hook requirements, when at least one POTS terminal is in the off-hook state.
- Transitional requirements, when one POTS terminal is in the transition from the on-hook to the off-hook state or vice versa.

On-hook voice band electrical requirements shall be met with a DC feeding voltage of 50 V, and using the (voice band) impedance model Z_{ON} , in a high impedance Z_{OnHI} and low impedance Z_{OnLI} variant as given in [Clauses 5.2.4](#) and [5.2.5](#) of the present document.

On-hook requirements are tested with a DC load of several $M\Omega$ and a negligible current. However, it should be noted that in certain networks there may be on-hook signalling requiring a DC loop current in the range of 0,4 mA to 2,5 mA flowing through the distributed filter. In this case the AC impedance model Z_{OnLI} is used to terminate the LINE and POTS port of the distributed filter at voice frequencies.

Off-hook electrical requirements shall be met with a DC current of 13 mA to 80 mA.

NOTE 1: It is recognized that in some networks DC feeding currents in steady state up to 100 mA or higher can occur. Similarly there are networks in which the maximum DC feeding current is limited, e.g. by the SLIC. This might allow designs adapted to these specific conditions.

NOTE 2: The transitional requirements were F.F.S. (for further study), but tests for transitional requirements are now specified in [Clause 6.13](#). However, this clause is optional. The TR-127 [i.15] of the Broadband forum provides the methodology to test this aspect of distributed filters. A tutorial text on TR-127 [i.15] is given in the informative [Annex H](#).

5.1.3 DC feeding and loading bridges

To inject a DC voltage and control the DC current separately from the AC impedances, a feeding circuit is used at the LE side and a loading (or holding) circuit at the TE side. These circuits, which we will call bridges throughout the text, have an equivalent electrical circuit as shown in the Figures 3 and 4. For balance $C1 \equiv C2$ and $L1 \equiv L2$.

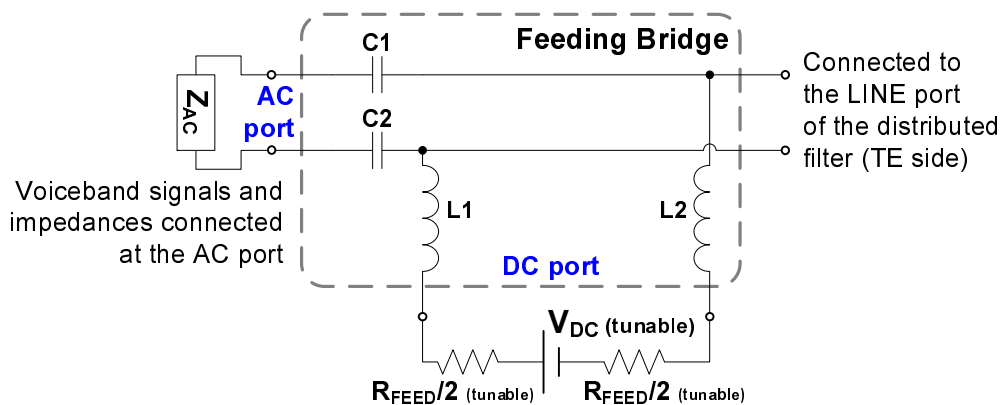


Figure 3: Feeding Bridge (connected to the LINE port of the distributed filter)

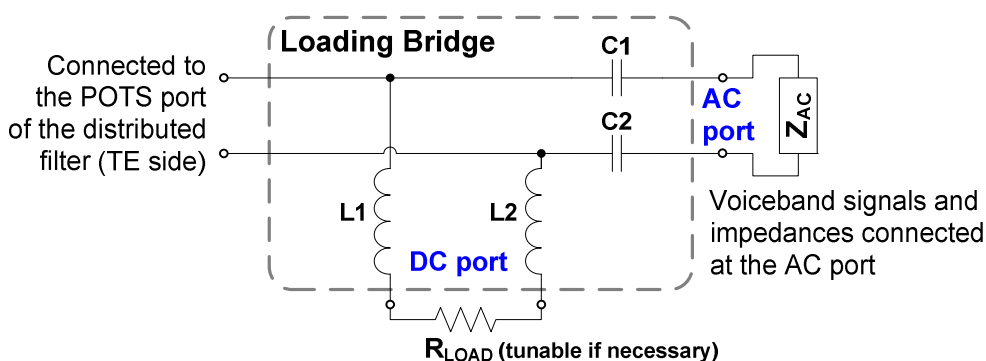


Figure 4: Loading Bridge (connected to the POTS port of the distributed filter)

NOTE 1: It is necessary to combine these feeding and loading bridges with the distributed filter test circuit diagrams of [Clauses 5.4, 5.5, 5.6](#) and [5.7](#). How this is done, is one aspect of the documents [i.3] and [i.5], which were already mentioned in note 2 in the [Foreword](#). However, to clarify the combination of feeding and loading bridges with the diagrams of [Clause 5.4](#), a few examples are also shown in [Annex G](#).

NOTE 2: The properties of the feeding and loading bridges should be sufficiently good, to prevent that measurements of distributed filter properties are affected by these bridges. E.g. in note 2 of [Clause 5.5.3](#) it is stated that their balance is important. Balance can be improved by using transformers. Testing above 1 MHz is not expected to be feasible with the same bridges, which are used for the POTS frequency range. Further information on building bridges particularly for higher frequencies is contained in [Annex J](#).

5.1.4 Ringing signal voltage

NOTE: For consistency the ringing test signals and the DC voltages superimposed to the 25 Hz to 50 Hz ringing should be defined in this clause. However, for historical reasons the [Clause 6.3](#) on ringing itself contains this particular information. Therefore, the levels of both the AC ringing and the associated DC are not defined here.

5.2 AC Terminating impedances

The impedances Z_{AC} in this clause are intended for AC only. The DC feeding conditions of the line shall be controlled separately, e.g. by inserting the appropriate DC feeding and loading bridges, as explained in [Clause 5.1.3](#).

5.2.1 Z_{refDSL} and Z_{DSL}

In many of the tests the LINE port (coinciding with the xDSL port) of the distributed filter is terminated with impedances called Z_{RefDSL} and Z_{DSL} . Z_{RefDSL} is the nominal design impedance of the DSL system and Z_{DSL} is an impedance model representing the input impedance of the xDSL transceiver (which implements a HPF). To simplify the measurements above 1 MHz, the source or load termination with Z_{DSL} may be replaced by Z_{RefDSL} , which is resistive; see [Clause A.1](#).

Both these substitute circuits, Z_{RefDSL} and Z_{DSL} are models, which shall be applied to a POTS distributed filter when verifying certain requirements. These models are intended for splitter or distributed filters specification in the context of the present document. The purpose of these model impedances is for distributed filter specification; they are not a requirement on the input impedance of the xDSL transceiver.

Depending on the type of xDSL involved, different values of Z_{RefDSL} and Z_{DSL} are applicable. They are described in [Clause A.1](#).

5.2.2 Z_R and Z_{SL} , off-hook impedances

For most requirements relating to voice band frequencies described in the present document, either the terminating impedances Z_R or Z_{SL} are used to terminate the POTS port or the LINE port. Z_R is the European harmonized complex impedance as defined in ES 201 970 [6] and ES 203 021-3 [3] and is shown in Figure 5; Z_{SL} is an impedance used in TBR 038 [1] to simulate a Short Line terminated in 600 Ω and is shown in Figure 6.

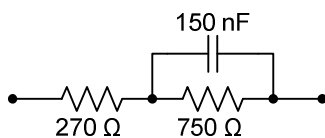


Figure 5: Impedance Z_R

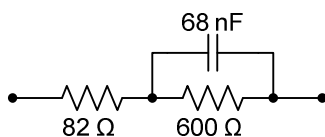


Figure 6: Impedance Z_{SL}

NOTE: In the case of filters to be deployed in some networks, alternative models of reference impedances instead of Z_R may be used when testing according to the distributed filter requirements in the present document.

5.2.3 Z_{RHF} , xDSL band impedance

For requirements relating to xDSL frequencies described in the present document, the terminating impedance Z_{RHF} is used to terminate POTS and LINE ports of the distributed filter. This is the European harmonized complex impedance Z_R with the modification for High Frequencies proposed in TR 102 139 [i.1]. This network is shown in Figure 7.

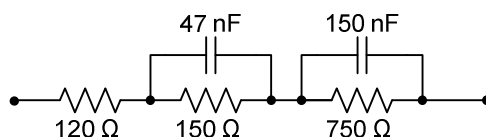


Figure 7: Impedance Z_{RHF}

For frequencies above 1 MHz it is known that it is difficult to source or to load the line with the Z_{RHF} impedance, particularly when equipment with a built-in 50 Ω impedance is used. In those cases a simple balun will load the line with an Ohmic impedance, rather than with the exact Z_{RHF} . To simplify the measurements at higher frequencies, the source or load termination with Z_{RHF} above 1 MHz may be replaced by the relevant resistive part, i.e. a 120 Ω resistor.

5.2.4 Z_{OnHI} , on-hook high impedance

For some on-hook requirements as defined in [Clause 5.1.2](#) in the present document, the terminating impedance is assumed to have a high impedance value and Z_{OnHI} is used. "OnHI" stands for **On**-hook **H**igh **I**mpedance.

Actual impedances will vary greatly especially over the xDSL frequency range and thus the impedance model adopted here is just intended for the verification of distributed filters. It is not intended to be an equivalent circuit for a POTS TE. The Z_{OnHI} impedance is shown in Figure 8.

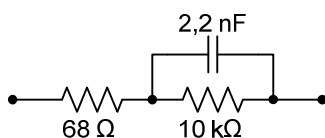


Figure 8: Impedance model Z_{OnHI}

5.2.5 Z_{OnLI} , on-hook low impedance

For some on-hook requirements, as defined in [Clause 5.1.2](#) in the present document, the terminating impedance is assumed to be a low AC impedance in the voice band and Z_{OnLI} is used. "OnLI" stands for **On**-hook **L**ow **I**mpedance.

The impedance specified in ES 200 778-1 [8] for the reception of Display Services depends on the modulation used (FSK, DTMF) and on the AC termination impedance option adopted by the TE manufacturer. Its expected modulus can range, depending from the frequency, between 1 kΩ and 2,4 kΩ for the low Ohmic case. However, for the purposes of the verification of distributed filters in the present document, a lower and more conservative Z_{OnLI} impedance termination has been preferred for the verification of filters performances, by adopting a 600 Ω resistive value.

5.2.6 Z_{OnHo} , impedance on-hook

For some off-hook requirements N parallel distributed filter are tested. One filter is terminated with an off-hook model (e.g. Z_R or Z_{SL}) attached to its POTS port, but in the presence of N-1 additional filters, in parallel and each terminated with an on-hook telephone model. The usage of the Z_{OnHI} was proposed for this, but it was shown that Z_{OnHI} is inappropriate, due to its low impedance, which is a worst case situation.

Therefore, to model terminal equipment in the on-hook state, in parallel with a single model of POTS equipment in the off-hook state, the terminating POTS impedance Z_{OnHo} could be used, which is more high-Ohmic, shown in Figure 9.

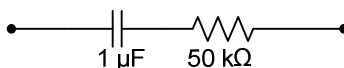


Figure 9: Impedance Z_{OnHo}

NOTE 1: The 1 μF capacitor is present for blocking the DC battery voltage on the line. It is specified here, because N-1 Z_{OnHo} impedances are needed in certain setups, and each of them needs to be DC decoupled. The usage of individual loading bridges for each instance of the Z_{OnHo} impedance would not be feasible.

NOTE 2: The **correct** use of the Z_{OnHo} to model on-hook impedances is not trivial at all. To correctly measure IL (see several clauses under [Clause 5.4](#)), the test set-up becomes quite complicated. Therefore, it was decided that the on-hook impedance attached to the N-1 filters in parallel with the main DUT could be replaced by infinity, i.e. the devices in parallel with the DUT are left open at the POTS port, and that the optional use of a finite Z_{OnHo} would be documented in the informative [Annex L](#).

5.2.7 Z_{ring} , load impedance for ringing

For some on-hook requirements in the presence of ringing signals, as defined in [Clause 6.3](#) in the present document, the terminating POTS impedance Z_{Ring} is used, modelling the terminal equipment on-hook. This impedance represents the minimum ringing load of the customer's premises equipment that any network is assumed to be able to support. The Z_{ring} impedance is dependent on the ringing frequency. The circuits are shown in Figure 10.

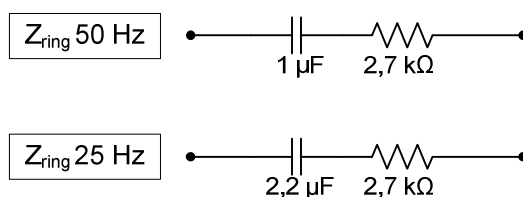


Figure 10: Impedances Z_{Ring} for 25 Hz and 50 Hz ringing

5.2.8 Z_{Meter} , impedance of the metering device

To model the metering device tuned to 12 kHz or 16 kHz, which counts the metering impulses during off-hook state of the telephone Z_{Meter} is used. 200 Ω is used for both the LE and the TE side, i.e. at the LINE port and at POTS port of the filter DUT.

5.3 Absence of a high pass filter

A distributed filter never includes a high pass filter in series between the line port of the filter and the xDSL port or the input port of the xDSL transceiver. This means that the LINE port and the xDSL port coincide for a distributed filter.

This is in contrast with the POTS central splitters and the ISDN or universal splitters. For POTS central splitters an optional highpass is allowed, as explained in TS 101 952-1 [11]. For ISDN splitters or universal splitters, a mandatory set of two DC blocking capacitors are required, as explained in TS 101 952-2 [12].

This largely simplifies the testing: at the LINE/xDSL port only a single xDSL impedance model is needed.

5.4 General transmission test setup

A tutorial on the "Optimal Transmission of POTS and xDSL Signals and their Separation" is in informative [Annex I](#).

For the transmission related tests specified in the present document, the following general test set-ups apply.

Besides the device under test N-1 additional parallel filters are used in the test setups. The minimum number of parallel filters that can be connected, for which the electrical requirements of the present document are fulfilled, depends on the filter class. The maximum number of parallel filters could be specified by the manufacturer.

Insertion Loss (IL):

To measure the propagation of certain signals with little loss or with some desirable strong attenuation from one port of the distributed filter to another port of the filter the measurement of the insertion loss (IL) is used in most cases.

Return Loss (RL):

Another important property of the distributed filter in the POTS band is the Return Loss (RL) at its POTS and LINE ports. This property indicates the way the impedance of the telephone line or equipment at one port is altered when the filter is inserted, when that impedance is measured at another port of the distributed filter. A high RL will result in less echoes being generated in the telephone network.

NOTE 1: All parts of the TS 101 952 contain a similar clause, with tutorial information about the set-up of the transmission tests. They differ in essential points, so careful reading of this clause is required.

NOTE 2: It is necessary that a central splitter or distributed filter fulfils certain requirements with and without xDSL load Z_{DSL} connected to the xDSL port, e.g. the IL, RL in the POTS band is measured this way. However, other requirements are only measured in the presence of Z_{DSL} , e.g. the IL in the DSL band. The presence or absence of Z_{DSL} is discussed in the clauses below and it is always mentioned in the requirement clauses in Clause 6.

NOTE 3: In the past, the RL measurement in the absence of the xDSL transceiver was not considered mandatory, because when the xDSL service is no longer delivered at the customer's premises, the customer could easily remove the filters as well. However, filters of superior quality should have good (or at least adequate) RL also in the absence of the xDSL transceivers.

NOTE 4: When N microfilters are tested in parallel for the off-hook condition, one filter DUT is loaded with the off-hook impedance, while the loads of the other DUTs are kept in the on-hook condition. Previously it was considered to load these N-1 filters with Z_{OnHo} . As this complicates the test set-ups, an open circuit is used to model the on-hook load at the POTS port of the N-1 parallel filters. This is still considered to be an acceptable way to assess the IL, the RL and other filter properties.

5.4.1 General definition of the Insertion Loss (IL) measurement

One of the transmission properties is the Insertion Loss (IL). For measuring IL the ratio is calculated between a voltage at the position of the **Device Under Test (DUT)** output, when the device is present and when it is absent. This means that we have to indicate the reference case (absence of the DUT). IL can indicate that a central splitter or distributed filter attenuates a signal very little, e.g. between the LINE and the POTS port in the POTS band. IL can also indicate that a central splitter or distributed filter attempts to isolate, e.g. by attenuating the signals in both directions between the POTS port and the xDSL port or the LINE port, in the xDSL band.

NOTE 1: It should be noted that for **passive** distributed filters the Insertion Loss (IL) is identical irrespective of the direction in which the IL is measured. This is the reciprocity theorem, which states that source and load can be interchanged for IL measurements. So in principle only one of the IL measurements is needed or if both measurements are performed, the results should be identical within the precision limits of the test.

NOTE 2: The source and the load impedances used in the IL measurements do not have to be identical, although this might be the case in many instances of the IL measurements in the present document.

NOTE 3: Measuring IL at higher frequencies requires care in the selection of the testing material, e.g. the BALUNS. Particularly care has to be taken regarding resonance effects between the central splitter or distributed filter and the baluns, which can influence the results at high attenuation values. It was noted that this influence could be dependent on the impedance of the POTS port of the distributed filter in the xDSL band, which is undefined.

5.4.2 POTS signal loss: IL between LINE port and POTS port

To measure the loss effect on the POTS signals resulting from the insertion of the distributed filter in the POTS path, the insertion loss (IL) is measured between the LINE port and the POTS port. Note that for measuring the insertion loss of a distributed filter, the measurement is done for 1 to N filters with and without impedance Z_{DSL} at the LINE port.

For measurements of the Insertion Loss (IL) between the LINE port and the POTS port, the two possible test set-ups are given in Figures 11 and 12, which will give identical result as explained in note 1 in [Clause 5.4.1](#). These IL measurements are done with the switch S_{DSL} open and closed, i.e. with and without the xDSL impedance Z_{DSL} present. The IL is measured over the relevant POTS frequencies, such as the voice band and the metering frequencies.

The test setups in Figures 11 and 12 contain N distributed filter devices in total.

To measure the effect of the DUT filter #1 alone, the switch S_{PAR} is kept open. To account for the effect caused by the N-1 additional distributed filters, these N-1 filters can be connected together with the distributed filter #1, which is under test, by closing the switch S_{PAR} . For simplicity (see note 2 in [Clause 5.2.6](#) and Note 4 under [Clause 5.4](#)), the parallel filters are left open at their POTS port.

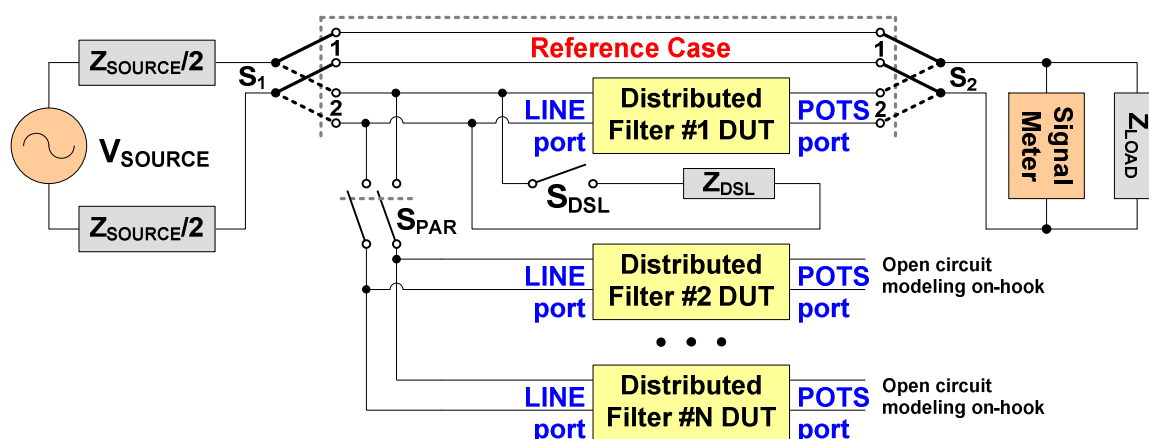


Figure 11: General test set up for transmission and IL testing from LINE port to POTS port

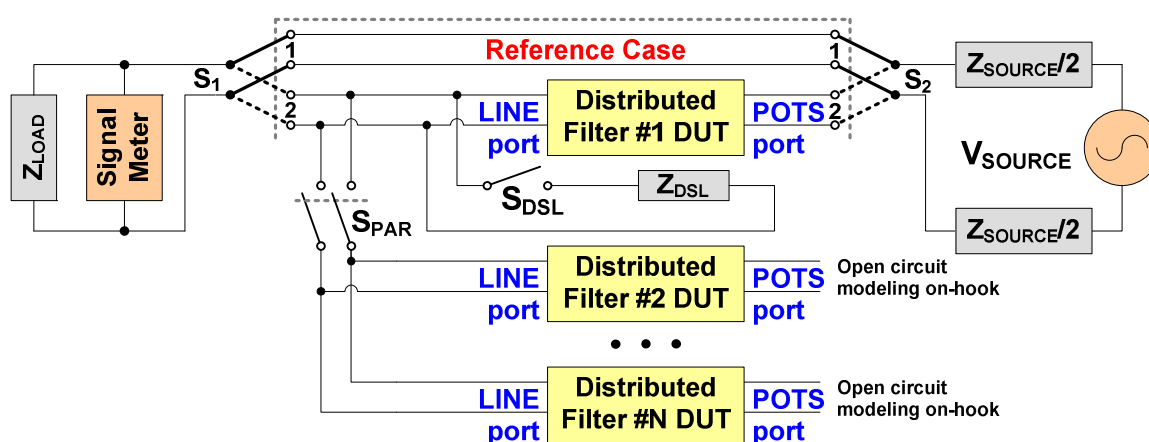


Figure 12: General test set up for transmission and IL testing from POTS port to LINE port

NOTE: The IL measurement with the switch S_{DSL} closed will not represent the IL of the distributed filter alone, but will include the loading effect of the Z_{DSL} impedance on the POTS signals. This means that part of the IL measured with the switch S_{DSL} closed is caused by the xDSL equipment. In [Annex D](#) the IL of the Z_{DSL} , i.e. the extra intrinsic IL caused by the xDSL equipment is explained. This means that for measurements in the POTS band the IL is increased adversely by the xDSL equipment. A similar effect exists for the RL (see note in [Clause 5.4.5](#)), as explained in the same [Annex D](#).

5.4.3 xDSL signal isolation: IL between LINE and POTS port

To measure the isolation caused by the distributed filter in the xDSL band, the loss effect resulting from the filter insertion must be assessed. The isolation is measured as the IL between the LINE port and the POTS port, which can be measured in both directions. Either test set-up of [Clause 5.4.2](#) can be used, with identical results. In this case the switch S_{DSL} is always kept closed, because measuring the xDSL signal isolation in the absence of the xDSL transceiver is meaningless. The measurements are done over the relevant xDSL frequency ranges, i.e. the xDSL pass band and the transition band.

NOTE 1: As also mentioned in TS 101 952-1 [11], the additional measurement between the POTS port and the xDSL port is not done for POTS splitters. For distributed filters this additional measurement is not done either.

NOTE 2: Identically to [Clause 5.4.2](#) the Z_{DSL} is not present during the reference measurement. Therefore, the IL of the distributed filter(s) is increased by the additional loss caused by Z_{DSL} . Also see [Annex D](#).

5.4.4 xDSL signal loss: IL between LINE port and xDSL port

A final transmission test is needed to measure the attenuation effect of input impedance of the distributed filter on the xDSL signals, which for a central splitter transit from the LINE to the xDSL port, or vice versa. For a distributed filter, the LINE port and the xDSL port coincide and the "loading effect" at the LINE port of the low pass filter must be assessed.

These transmission tests require a signal to be generated and measured at the LINE port. These tests will prove that this low pass filter does not affect the xDSL signals unnecessarily, i.e. does not attenuate, distort or add noise.

The two equivalent set-ups of the IL at the LINE port are shown in Figures 13 and 14. (The reference case has all low pass filters and their load impedance at the POTS port removed. This is equivalent to opening all switches S_i).

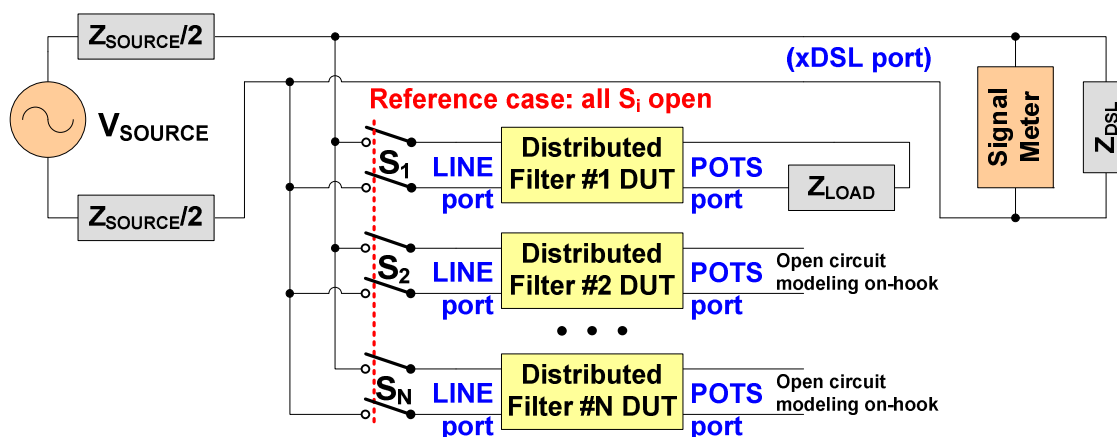


Figure 13: Test set-up for Insertion Loss LINE port to xDSL port

The signal direction can be from the LINE impedance to the xDSL port impedance Z_{DSL} (as in Figure 13) or inverted from Z_{DSL} as source to a load modelling a LINE impedance (as in Figure 14), but for passive circuits this does not change the measurement results (see note 1 in [Clause 5.4.1](#)).

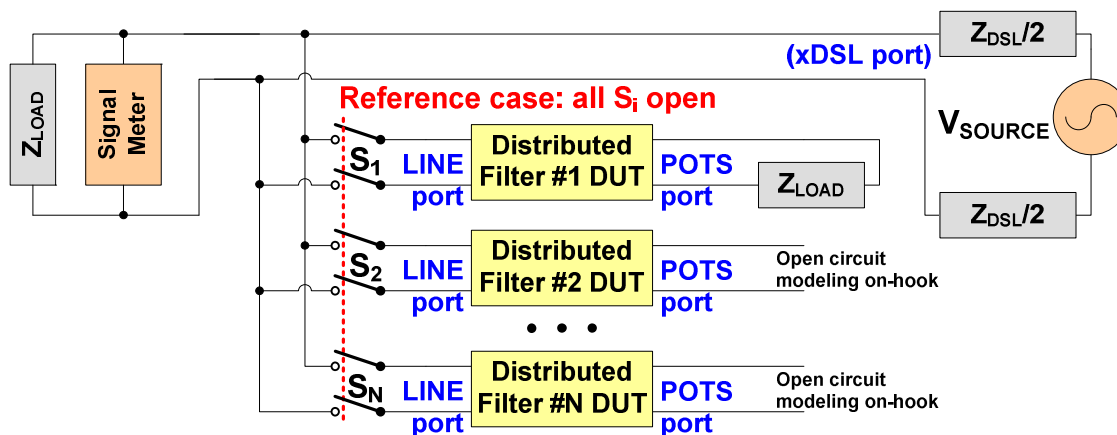


Figure 14: Test set-up for Insertion Loss to xDSL port to LINE port

The load Z_{LOAD} at the POTS port of the first filter DUT in the Figures 13 and 14 shall be modelled as a short circuit, an open circuit and some relevant POTS reference impedances such as Z_{RHF} . For simplicity, the other filters have an open circuit at their POTS port.

NOTE 1: Loading the POTS port of the distributed filter with a short circuit, an open circuit and the nominal Z_{RHF} impedance covers a sufficiently wide range of impedances to cover all practical load situations at this port. The impedance changes at the POTS port can affect the xDSL, which could suffer CRC errors and might even lose synchronization. This can be checked with the TR-127 [i.15] methodology as described in the note in [Clauses 6.11.2](#) and in [6.13](#). The whole TR-127 [i.15] based methodology is now stable.

NOTE 2: The insertion loss could be measured with the addition of the complete xDSL impedance model. E.g. the IL from LINE to xDSL port could be measured on the $100\ \Omega$ impedance in the $Z_{LOAD} = Z_{DSL}$, but this would result in a more complicated set-up that e.g. can be found in TR 101 953-1-2 [i.4] and TR 101 953-2-2 [i.6], with identical results. The relevant diagrams are added in the informative [Annex E](#).

5.4.5 General definition of the Return Loss

The measurement of the Return Loss (RL) of a central splitter or distributed filter at a given port, indicates the way the impedance of the telephone line or equipment connected at another port is changed due to the insertion of the central splitter or distributed filter as measured at the given port.

Normally POTS equipment (connected at the LE or at the TE side) is constructed to match the reference line impedance Z_R or $600\ \Omega$. When the POTS equipment at the LE and at the TE side are well matched, there will be little echoing of the POTS signals. However, the insertion of the central splitters or distributed filters could alter the generation of the echoes. Example: if the Z_R impedance is connected at the LINE port, and if this impedance is seen at the POTS port with little change, the echoes stay low. However, when the impedance Z_R is connected to the LINE port and if then the impedance seen at the POTS port differs largely from Z_R , the telephone equipment at the POTS port will experience an undesirable enhancement of the echoes and/or sidetone.

The generalized definition of RL contains a reference impedance Z_{Ref} . The generic RL formula (below) compares the input impedance Z_{IN} with Z_{Ref} . The RL value will be higher, when Z_{IN} and Z_{Ref} are more similar.

$$RL = 20 \cdot \log\left(\frac{|Z_{Ref} + Z_{IN}|}{|Z_{Ref} - Z_{IN}|}\right)$$

NOTE: For central splitters and distributed filters the RL is measured in the presence and absence (optional) of the xDSL service. This means that the RL is measured for either the splitter or filter low pass section alone or for the combination of the low pass section, the optional high pass and Z_{DSL} termination. Therefore, the RL measurement with the switch S_{DSL} closed will include the effect of the Z_{DSL} impedance on the return loss. This means that a significant part of the RL measured with the switch S_{DSL} closed can be caused by the xDSL equipment. In [Annex D](#) the effect of the Z_{DSL} on the RL is shown, i.e. the intrinsic RL degradation as caused by the xDSL equipment.

5.4.6 Return Loss test set-up at LINE port and POTS port

The Return Loss (RL) measurements are normally limited to the POTS bands and are also limited to the LINE port and the POTS port. For the xDSL signal stream there is no need for RL to be measured. For POTS services the RL is measured in the presence and absence of the xDSL service, i.e. with Z_{DSL} connected (mandatory) and removed (optional) by acting on the switch S_{DSL} .

For the purpose of measuring RL of central splitters or distributed filters, Z_{LOAD} is used as Z_{Ref} in the general formula in [Clause 5.4.5](#). In this way the "transparency" of the splitter or filter can be appreciated.

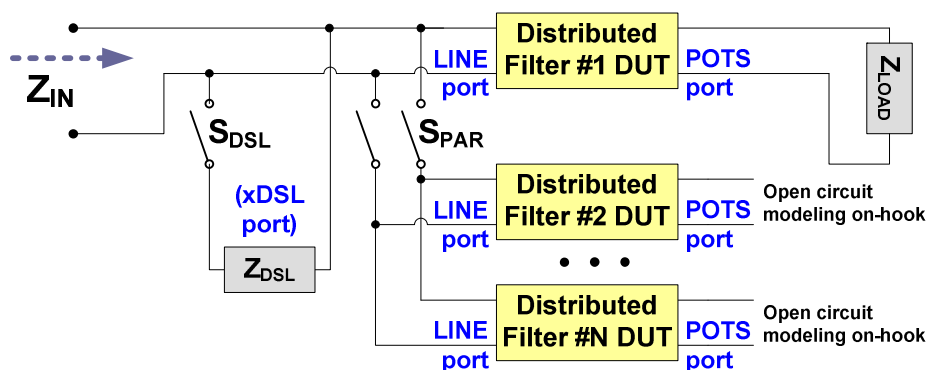


Figure 15: Test set up for Return Loss testing at the LINE port

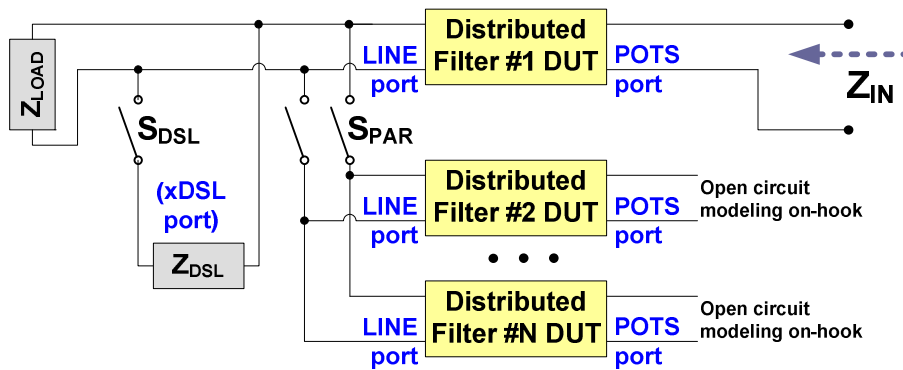


Figure 16: Test set up for Return Loss testing at the POTS port

The Return Loss (RL) for central splitters and distributed filters is defined in the following formula:

$$RL = 20 \cdot \log \left(\frac{|Z_{LOAD} + Z_{IN}|}{|Z_{LOAD} - Z_{IN}|} \right)$$

For a distributed filter we define the RL at the POTS port and at the LINE port, which are found by measuring the input impedance Z_{IN} as shown in the Figures 15 and 16.

- For the RL at the LINE port, we measure the Z_{IN} according to Figure 15.
- For the RL at the POTS port, we measure the Z_{IN} according to Figure 16.

For central splitters the RL is measured in the presence and absence of the Z_{DSL} , i.e. with the S_{DSL} switch in Figures 15 and 16 closed and open, as specified in TS 101 952-1 [11]. However for distributed filters the RL shall only be measured in the presence of Z_{DSL} , i.e. with the switch S_{DSL} closed. The measurement of the RL in the absence of Z_{DSL} is optional.

The RL shall be measured for a single distributed filter device, and for a set of N devices, i.e. with the S_{PAR} switch in Figures 15 and 16 open and closed.

The N-1 devices in parallel with the device under test are left open at the POTS port.

For the practical realization of the RL measurements bridge-based circuit diagrams are included in [Annex F](#).

5.5 Unbalance measurement

An additional property of a central splitter or distributed filter at its ports is the unbalance, by which common mode signals are converted to differential signals, which can affect both the POTS and the xDSL transmission.

In the POTS band the balance has to be good at both the POTS and the LINE port. In the xDSL band the balance has to be such that minimal amounts of disturbing differential signal are found at the LINE port or the xDSL port.

5.5.1 General definition of Longitudinal Conversion Loss

One of the balance properties is the Longitudinal Conversion Loss (LCL). For measuring LCL a common mode signal is injected at one port, while the other ports are connected to appropriate differential and common mode impedances.

The LCL is the ratio between the common mode voltage and the (undesirable resulting) differential voltage at the same port.

In the POTS band the LCL has to be good at both the POTS port and the LINE port. In the xDSL band the LCL has to be good mainly at the LINE port. Therefore, an LCL value at the POTS port in the xDSL band should be imposed, but it can be limited to a smaller frequency range.

5.5.2 General definition of Longitudinal Conversion Transfer Loss

A second balance property is the Longitudinal Conversion Transfer Loss (LCTL). For measuring LCTL a common mode signal is injected at one port, while the other ports are connected to appropriate differential and common mode impedances.

The LCTL is the ratio between the common mode voltage injected at one port and the (undesirable) differential signal resulting at another port.

In the xDSL band the LCTL is used to evaluate the extent that common mode noises entering via the POTS port are transiting through the central splitter or distributed filter and converted into differential signals at the LINE port.

5.5.3 LCL and LCTL test set-up

The basic test set-up for measuring Unbalance about Earth (UaE) at the POTS port, with the termination at the LINE port is shown in Figure 17. The xDSL port is terminated with a balanced Z_{RefDSL} impedance, defined in [Clause 5.2.1](#).

In the case of measuring at the LINE port with the termination at the POTS port, the test set-up of Figure 18 is used, which is derived from Figure 17 by reversing the POTS and LINE ports.

NOTE 1: For distributed filters there is no need to measure the balance from LINE port to xDSL port, a measurement that is needed **only** for central splitters.

For LCL the source (U_0) and the measurement (U_{T1}) point are always located at the same port. For LCTL the source (U_0) is at one port and the measurement point (U_{T2}) is at the termination port.

This requirement shall be met for both the on-hook and off-hook case. The DC feeding is as specified in [Clause 5.1.2](#).

For measurements at frequencies above the voice band, for reasons of practical testing a $150\ \Omega$ impedance should be used in series with the longitudinal source (i.e. S_1 in Figures 17 and 18 should be open).

The unbalance about earth is calculated by using the following equation. Use U_{T1} or U_{T2} for LCL and LCTL respectively in Figure 17. In Figure 18 use U_T for LCL.

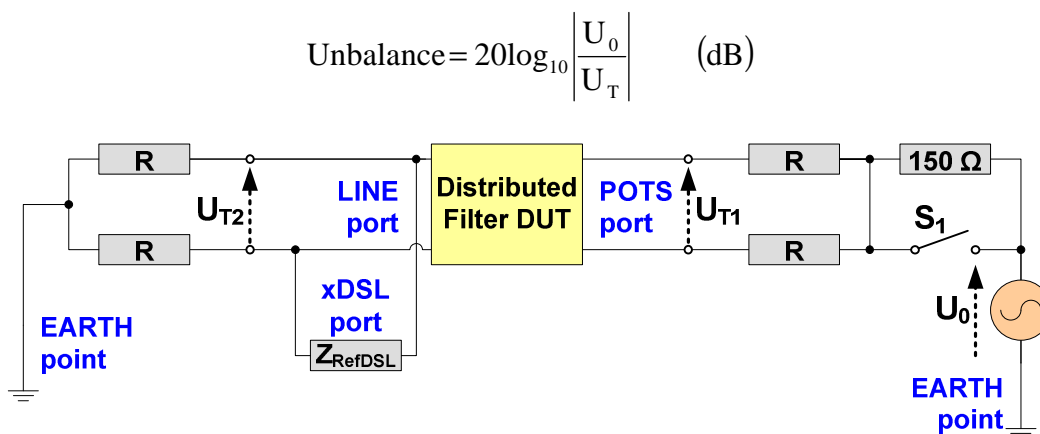


Figure 17: UaE; LCL or LCTL measurement test set-up POTS port to LINE port

All notes apply to Figures 17 and 18.

NOTE 2: The $150\ \Omega$ models the longitudinal impedance of the line or of the POTS circuits.

NOTE 3: The DC current feeding circuitry is not shown. Care should be taken that the feeding bridge is implemented in such a way not to have any significant influence on the accuracy of the measurement. Indeed, it is quite difficult to measure LCL and LCTL at high frequencies, in the presence of the feeding and loading bridges of [Clause 5.1.3](#). Indeed, practical implementation of such feeding and loading bridges is known to affect the balance measurement. If necessary the measurements have to be made with different bridges for different frequency ranges. Combining the DC feed with the LCL and LCTL test diagrams is one aspect of the documents [i.3] and [i.5], which were already mentioned in the [Foreword](#) in note 2. Similar examples of adding the DC feeding circuitry are also shown in [Annex G](#).

NOTE 4: If the effect of DC current is balanced by design (e.g. by the use of transformers) a waiver of the measurement in the presence of DC current may be granted.

NOTE 5: For resistances R an equivalent circuit according to ITU-T Recommendation O.9 [5] can be used.

NOTE 6: As the distributed filters have no earth terminal, the test should be performed with the filter placed on an earthed metal plate of a sufficiently large size.

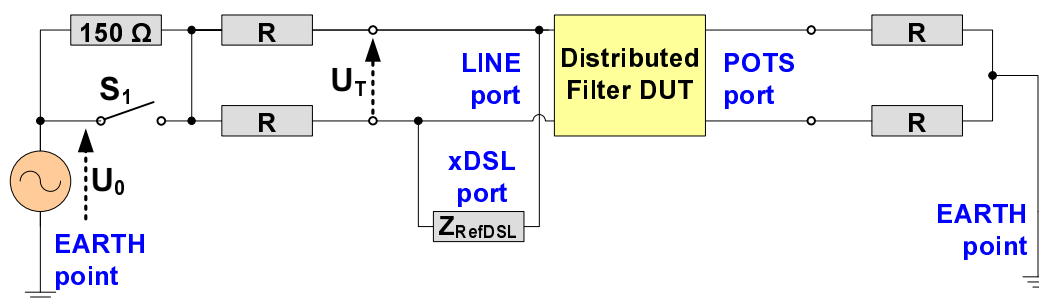


Figure 18: UaE; LCL measurement test set-up LINE port to POTS port

5.6 Noise measurement

The measurement of noise in the POTS and the xDSL band is only required for active/dynamic distributed filters.

5.6.1 Psophometric noise in the POTS Band

The methodology for testing noise of active/dynamic filters is F.F.S. and it is introduced in the informative [Annex K](#).

5.6.2 Noise in the xDSL Band

The methodology for testing noise of active/dynamic filters is F.F.S. and it is introduced in the informative [Annex K](#).

5.7 Common Mode Rejection Ratio measurement

For central splitters the CMRR is defined. However, it is not very useful to include common mode rejecting device in a distributed filter, and therefore there is no need to introduce the measurement of the CMRR for distributed filters.

NOTE: In the case of a central splitter a single common mode (CM) rejection device is used, e.g. a transformer, which achieves the best possible balance. The CM rejection device is efficient in removing the common mode noise that is picked up at the POTS wiring at the customer's premises. However, in a distributed filter this extra CM device is increasing the complexity substantially, because typically the number of coils or transformers in the filter is lower than for a splitter. Moreover, this extra device would need to be present in each distributed filter. Finally the amount of common mode noise picked up by a phone would be limited, because the length of cable on which common mode noise can be induced into the cabling is quite limited. Only the CM noise on the cable between phone and filter would be filtered by the CM device. All CM noise picked up in the rest of the in-home network would not be filtered by the CM device. This means that for distributed filters it is of limited use to include a common mode rejecting device: it would have little to reject, it would not reject the majority of the induced noise and it would be complex, as it would be present N times, i.e. for each distributed filter. Therefore, CM devices are not used in distributed filters, and there is no need to test their effect.

6 Distributed filter requirements

6.1 Classification of distributed filters according to requirements

The electrical requirements for distributed filters in the present document are classified into three categories. We will discriminate **basic** filters, **standard** filters and **enhanced** filters based on selected requirement criteria.

In this clause a number of general requirements are imposed on all categories of filters, without discrimination. The criteria for discriminating the categories of distributed filters are:

- 1) **POTS band performance**, i.e. IL and RL at all ports, with and without Z_{DSL} for 1 or 2 devices in parallel.
- 2) **Extended parallel operation** in the POTS band when 3 or more filter devices are used in parallel.
- 3) **Rejection in the xDSL band** in terms of isolation and rejection, reduced when compared to central splitters.
- 4) **Degradation of the xDSL transmission**: xDSL performance and quality drop compared to central splitters.

6.1.1 Justification of the classification

The classification is introduced, because many **Basic distributed filters** exist on the market with only a minimal number of components, which are still adequate for use in high speed internet applications with only one or two POTS terminals connected. Also the POTS quality for such basic filters is often acceptable under these conditions. Typically a basic filter has only two coils, which results in a simple second order filter. As soon as more than two filters are put in parallel the use of standard or enhanced filters (see below) might be needed, unless the user accepts a substantial drop of the POTS and xDSL quality, as compared to what can be achieved with a central splitter as specified in TS 101 952-1 [11].

Standard distributed filters are required e.g. when the high IL of several parallel filters degrades the POTS audio quality or impedes the reception of CLIP signals, or e.g. when certain sensitive phones cannot handle the upstream ADSL signal residue, which results in noise in the earpiece. Up to three standard filters can be connected in parallel without impairing the POTS quality beyond unacceptable limits. These filters typically contain at least 4 coils, or two transformers.

Enhanced filters, with typically up to 6 coils allow connecting up to 4 devices in parallel. However, due to the complexity of the enhanced filters, many operators may allow the use of the basic or standard filters, suggesting the use of enhanced filters only when particular deployment issues arise.

6.1.2 Basic filter requirements

Basic filters have "standard" performance for a single device and a minimal performance for 2 parallel devices, considered adequate for most POTS users in high speed internet xDSL applications. A basic filter has:

- 1) **Adequate POTS performance** (IL, IL distortion and RL) for a pair of filters.
- 2) **Degraded parallel operation** in the POTS band, when 3 or more parallel devices are used.
- 3) **Basic rejection of xDSL signals** in the stop band, which could be inadequate for certain sensitive telephones.
- 4) **Acceptable xDSL degradation**: For $N > 1$ a non-negligible but unavoidable effect on the xDSL transmission.

6.1.3 Standard filter requirements

Standard filters, which have the following improved properties, appreciated by more demanding users, or imposed by operators requiring a better quality:

- 1) **Improved POTS performance**: IL and RL in the POTS band better than a basic filter.
- 2) **Improved parallel operation**: at least the performance of a single basic filter, but for at least 3 parallel devices.

- 3) **Improved rejection of xDSL signals:** substantially better rejection in stop and transition band.
- 4) **Minor xDSL degradation:** negligible effect on the DSL transmission.

6.1.4 Enhanced filter requirements

Enhanced filters, which have the following enhanced properties, typically can be used when particular deployment issues arise:

- 1) **Enhanced POTS performance:** an audio quality closer to a central splitter.
- 2) **Enhanced parallel operation:** for at least 4 parallel devices.
- 3) **Enhanced rejection of xDSL signals:** substantially better rejection in stop and transition band.
- 4) **Minor xDSL degradation:** negligible effect on the DSL transmission.

6.1.5 Option A and Option B as defined for central splitters

For central splitters requirements were divided in two categories, Option A and Option B, with requirements that are identical with the exception of the clauses on POTS band return loss in the off-hook state and the off-hook isolation in the xDSL band.

The original discrimination between Option A and Option B filters is based on their use in networks with a single reference impedance and in networks with multiple impedances. The idea was that for a single reference impedance the RL of a splitter in the POTS band can be tuned to be quite good, while optimising the RL of a splitter for multiple impedances is not necessary or not feasible.

Option A filters: When the RL of the filters must be measured with multiple impedances, one has to accept that the RL is lower. This allows the bandwidth of the filter to be narrower, achieving a stronger IL in the xDSL band.

Option B filters: When the RL of the filters is measured on a single impedance, then it makes sense to enhance the RL. This requires the bandwidth of the filter to be wider, and the IL in the xDSL band must be relaxed somewhat.

Further information can be obtained in the [Clause 6.1.7](#) and in the tutorials in [Annex C](#) and in clauses 6.1.1 and 6.1.2 of TS 101 952-1 [11].

6.1.6 Option A and Option B as used for distributed filters

NOTE: As the RL requirements of the Option A and Option B are well known and already used to specify the requirements of distributed filters, we will keep this nomenclature.

Depending on the quality of the RL requirement we will discriminate between Option A and Option B, borrowing these names from TS 101 952-1 [11], on central splitters. For distributed filters the two options A and B of the RL requirements are still loosely coupled to the isolation in the xDSL band. This is explained in the [Clause 6.1.7](#) and in [Annex C](#).

6.1.7 Correlation and trade-offs between filter requirements (for information)

When filters are designed several correlations between the requirements must be observed. Therefore, trade-offs must be made to achieve an acceptable complexity of the filters. The following correlations and trade-offs can be listed:

- POTS band requirements for filters (and splitters) are inversely linked with the IL in the xDSL band.
- POTS band requirements achieved by a single filter will degrade when multiple devices are put in parallel.
- Higher complexity is needed to achieve better POTS band and xDSL band properties, particularly when large numbers of parallel filter devices are installed, while attempting to keep the quality close to master splitters.
- Installing multiple parallel filters causes different RL effects at the POTS port and at the LINE port.

- There is also a different effect on the RL at POTS and LINE port when the xDSL transmitters are removed, while the filters are kept in the installation, which might happen unintentionally, i.e. by mistake.

Particularly the issues of installing parallel devices were never clearly assessed in older documents. In the present document there are requirements for testing parallel devices. In the previous version of the present document the requirements were measured only for a single device. This causes discrepancies between devices according to the previous version and the present version. In the present document it is attempted to achieve a good compromise between the requirement in the POTS band, the xDSL band and the parallel operation. Older devices (i.e. according to the previous version) might combine optimal RL in the POTS band with optimal IL in the xDSL band for a single device, but therefore they will suffer issues when parallel devices are deployed.

The informative [Annex C](#) contains examples of these trade-offs.

6.2 DC requirements

DC requirements are tested for a single distributed filter. There is no need to test this in parallel operation.

6.2.1 DC Insulation resistance between A-wire and B-wire

The DC resistance R_{AtoB} between the A-wire and B-wire at both the LINE and POTS port of the filter, when tested with 100 V DC, shall not be less than 5 M Ω .

NOTE: This requirement takes into account the minimum total DC Resistance between A and B wires that is acceptable for TE complying with ES 203 021-3 [3]. It is recognized that the majority of passive splitters or distributed filters will achieve DC Resistance between A and B wires of at least 20 M Ω .

6.2.2 DC series resistance

The DC resistance R_{DC} between the A-wire to the B-wire at the LINE port with the POTS port short circuited, or at the POTS port with the LINE port short circuited shall be less than or equal to 50 Ω .

This requirement shall be met for the feeding conditions described in [Clause 5.1.2](#) for both on-hook and off-hook conditions.

6.2.3 DC signalling

The POTS line typically may, according ES 201 970 [6], power the TE with a battery e.m.f. voltage from 38 V_{DC} to 78 V_{DC}. When the POTS terminal is off-hook, the voltage appearing across the filter ports will normally be lower depending on the characteristics of the terminal and the feeding bridge and on the line length.

The filter shall not significantly affect any POTS DC signalling in such a manner that would prevent it from performing its intended function.

The following DC signalling methods are commonly used:

- register recall signalling (specified in ES 201 729 [9]);
- reversals in polarity (commonly used in many networks to signal various events to the TE);
- loop disconnect dialling (specified in ES 201 187 [10]), although DTMF signalling is strongly preferred in combination with xDSL;
- K-break referred to in ES 201 970 [6], clause 14.6;
- CLI and other enhanced signalling, according EN 300 659-1 [7]; and
- ES 200 778-1 [8] may also be associated to some special DC signals.

NOTE 1: Clause 14 of ES 201 970 [6] refers to these signalling methods.

NOTE 2: Although there is no clear test method given to prove this, by design a typical passive and static filter with sufficient bandwidth will not affect any of the POTS DC signalling methods above.

6.3 Ringing frequency requirements

The DC feeding current conditions of [Clause 5.1.2](#) are not applicable to these requirements. The specific DC feeding voltage conditions for ringing tests are specified in the [Clauses 6.3.1](#) and [6.3.3](#).

These tests can be limited to a **single distributed filter**.

6.3.1 Ringing voltage drop at 25 Hz and 50 Hz

Ringing signals with frequencies of 25 Hz and 50 Hz shall be used. The other test conditions are listed in Table 1.

The maximum voltage drop at the load impedance due to the insertion of one filter is tested from LINE port to POTS port, according to the test set-up of Figure 11 in [Clause 5.4.2](#), with the switches S1 and S2 in position 2. It shall be not more than V_{RD} (abbreviation of $V_{\text{Ring-Drop}}$), which has a value of $2 V_{\text{RMS}}$. This requirement shall be tested with the switch S_{DSL} in Figure 11 closed.

The test can be limited to the transmission test of a **single distributed filter**. Adding additional parallel filter devices would hardly affect the test result.

Table 1: Test conditions Voltage drop at 25 Hz and 50 Hz

Impedance of signal source	850 Ω (resistive)
Impedance of the load	Z_{ring} (defined Clause 5.2.7)
Open voltage of the AC test signal source	35 V_{RMS}
Level of the DC feeding voltage	60 V DC

6.3.2 Z_{InRing} impedance at 25 Hz and 50 Hz

The LINE port of a single distributed filter shall have an impedance Z_{InRing} (when measured between the A-wire and the B-wire) at 25 Hz greater than 40 k Ω or at 50 Hz greater than 36 k Ω if applicable. The test setup measure the input impedance at the LINE port as in Figure 15 in [Clause 5.4.6](#). The switches S_{PAR} and S_{DSL} are left open. When testing at the LINE port the POTS port shall be kept open circuited, i.e. Z_{LOAD} in Figure 15 is infinite.

NOTE: A filter with an impedance of 40 k Ω will typically draw only 1/10 of the current of a reference ringer load of 4 k Ω .

6.3.3 Total harmonic distortion at 25 Hz and 50 Hz

The filter shall be able to transfer the ringing signals to the AC-load without significant distortion. This is tested with two sets of source and feeding voltages, as given in Table 2.

The test can be limited to the transmission test of a **single distributed filter**. The test shall be carried out at 25 Hz and 50 Hz. With those voltages applied, the total harmonic distortion (THD_{Ring}) of the AC signal shall be less than 10 %.

The test setup applies signal at the line port of the filter as given in Figure 11 in [Clause 5.4.2](#) with the switches S_1 and S_2 in position 2. This THD requirement is also needed to protect the xDSL transmission and therefore, it shall be met with the switch S_{DSL} in Figure 11 closed. The switch S_{PAR} is left open.

Table 2: Test conditions THD at 25 Hz and 50 Hz

	Test 1	Test 2
Open voltage of the AC test signal source	100 V _{RMS}	50 V _{RMS}
Level of the DC feeding voltage	50 V DC	78 V DC
Frequency of the signal source	25 Hz and 50 Hz	
Impedance of signal source	850 Ω (resistive)	
Impedance of the load, dependent of the ringing frequency	Z _{ring} (defined in Clause 5.2.7)	

6.4 POTS pass band loss requirements (on-hook)

The measurement is an insertion loss according to [Clause 5.4.2](#) between LINE port and POTS port, which is independent of the direction.

The first filter DUT is terminated with the appropriate on-hook impedance at the POTS port (see further).

It is mandatory to do the measurement with the S_{DSL} switch open and closed, i.e. with Z_{DSL} absent and present.

6.4.1 On-hook requirement for the case of high impedance termination

The IL_{PBOnH} of the filter in the range 200 Hz to 2,8 kHz shall be within the range -4 dB to +4 dB for the on-hook case with high impedance termination. The on-hook DC feeding shall be as specified in [Clause 5.1.2](#).

The test shall be executed with the combinations of source and load impedances as specified in Table 3.

Table 3: Impedances and test setup for the on-hook voltage gain test

Test setup reference	Impedance of signal source	Impedance of the load at the POTS port: Z _{LOAD}
Clause 5.4.2	Z _R (defined in Clause 5.2.2)	Z _{OnHI} (defined in Clause 5.2.4)
NOTE: Level of the test signal = -4 dBV emf.		

The test result shall be reported for 1 to N devices as specified in the Table 4, i.e. with the S_{PAR} switch open and closed, and with the S_{DSL} switch closed, i.e. with Z_{DSL} present. The N-1 parallel filters are left open at their POTS port.

Table 4: Minimal number of parallel filters (N) in the test setup

Filter class	N
Basic	2
Standard	3
Enhanced	4

6.4.2 On-hook requirement for the case of low impedance termination

The requirements of this clause are applicable to networks providing Display and Related Services, as specified in ES 200 778-1 [8]. The DC feeding shall be as specified in [Clause 5.1.2](#) for the on-hook case, i.e. from 0,4 mA to 2,5 mA.

Both the source and load shall be set at Z_{OnLI} defined in [Clause 5.2.5](#).

The test result shall be measured for **1 filter only**, i.e. with the S_{PAR} switch open, and with the S_{DSL} switch closed, i.e. with Z_{DSL} present. The maximum IL of one distributed filter (S_{PAR} open) in the frequency range 200 Hz to 2,8 kHz shall be as specified in Table 5.

Table 5: Maximum IL (IL_{MaxOnH})

Filter class	Frequency Range	(IL_{MaxOnH}) (= Max IL)
Basic quality		$\leq 2,5$ dB
Standard quality	200 Hz to 2,8 kHz	≤ 2 dB
Enhanced quality		≤ 2 dB

The maximum variation of the IL (i.e. the difference between maximum and minimum IL value) of one distributed filter (S_{PAR} open) in the frequency range 200 Hz to 2,8 kHz shall be as specified in Table 6.

Table 6: Maximum IL variation (IL_{VarOnH})

Filter class	Frequency Range	IL_{VarOnH} (= Max IL - Min IL)
Basic quality		$\leq 2,5$ dB
Standard quality	200 Hz to 2,8 kHz	≤ 2 dB
Enhanced quality		≤ 2 dB

6.5 POTS Pass band loss requirements (off-hook)

The measurement is an insertion loss according to [Clause 5.4.2](#) between LINE port and POTS port, which is independent of the direction.

The level of the test signal = -4 dBV emf. The off-hook DC feeding current is specified in [Clause 5.1.2](#).

The test shall be executed with Z_R (defined in [Clause 5.2.2](#)) as source and load impedance. Measuring with 600 Ω as source and load is no longer required.

The test result shall be reported with the S_{PAR} switch open and closed, i.e. for a single device and for the case with a total of N devices, one as device under test and N-1 devices in parallel. The N-1 parallel filters are left open at their POTS port.

It is mandatory to do the measurement with the S_{DSL} switch open and closed, i.e. with Z_{DSL} absent and present.

NOTE: Passing the IL requirement with the Z_{DSL} absent is normally not an issue because Z_{DSL} will tend to worsen the IL.

The maximum IL of distributed filters in the frequency range 300 Hz to 4 kHz shall be as specified in Table 7.

Table 7: Maximum IL ($IL_{MaxOffH}$)

Filter class	Frequency Range	Number of devices in parallel			
		N = 1	N = 2	N = 3	N = 4
Basic quality	300 Hz to 4 kHz	$\leq 2,5$ dB	≤ 3 dB	n.s. (see note)	-
Standard quality		≤ 2 dB	$\leq 2,5$ dB	≤ 3 dB	n.s. (see note)
Enhanced quality		≤ 2 dB	$\leq 2,25$ dB	$\leq 2,5$ dB	≤ 3 dB

NOTE: n.s. Not specified – but results to be reported.

The maximum variation of the IL (i.e. the difference between maximum and minimum IL value) of distributed filters in the frequency range 300 Hz to 4 kHz shall be as specified in Table 8.

Table 8: Maximum IL variation (Max IL - Min IL) ($IL_{VarOffH}$)

Filter class	Frequency Range	Number of devices in parallel			
		N = 1	N = 2	N = 3	N = 4
Basic quality	300 Hz to 4 kHz	$\leq 2,5$ dB	≤ 3 dB	n.s. (see note)	-
Standard quality		≤ 2 dB	$\leq 2,5$ dB	≤ 3 dB	n.s. (see note)
Enhanced quality		≤ 2 dB	$\leq 2,25$ dB	$\leq 2,5$ dB	≤ 3 dB

NOTE: n.s. Not specified – but results to be reported.

6.6 POTS Passband return loss requirements (off-hook)

The return loss (RL) at both the POTS and LINE port of the filter shall be measured according to [Clause 5.4.6](#), as in Figures 15 and 16, i.e. **at both ports**.

At the LINE port the test result shall be reported with the S_{PAR} switch open and closed, i.e. for a single device and for the case with a total of N devices, one as device under test and N-1 devices in parallel. The N-1 parallel filters are left open at their POTS port.

Return loss testing is to be carried out under the off-hook DC feeding current of [Clause 5.1.2](#).

As shown in Figures 15 and 16 Z_{LOAD} with appropriate values shall be connected, as indicated specifically in the [Clauses 6.6.1](#), [6.6.2](#) and [6.6.3](#).

It is mandatory to do the measurement with the S_{DSL} switch closed. Doing the test with the Z_{DSL} absent is optional.

NOTE 1: At the LINE port it is more difficult to achieve a good RL when Z_{DSL} is absent. Indeed, particularly at the LINE port of a splitter or distributed filter the RL is improved by the presence of Z_{DSL} . However, at the POTS port the RL typically improves in the absence of the Z_{DSL} , i.e. when the S_{DSL} switch is opened.

NOTE 2: The RL requirements in the following clauses are a linear interpolation in dB versus a log(frequency) scale.

6.6.1 Return loss requirements at the POTS port

The RL **at the POTS port** is measured for a single device only. For multiple parallel filters the RL degradation at the POTS port will result in a side tone enhancement, which is only reported but not considered a strong requirement.

For both option A and option B the requirements for filters at the POTS port are the same as for central splitters.

6.6.1.1 Return Loss at the POTS port for Option A

At the POTS port the RL Option A is measured for a single filter only, as shown in Table 9 and Figure 19.

Table 9: Return loss requirements, Option A, at the POTS port for all filters

Load & Source Impedance	Frequency	Number of parallel devices
		N = 1
Z_{SL} , Z_R (defined in Clause 5.2.2) (Note the use of Z_{SL} , but only for testing Option A at the POTS port)	300 Hz	12 dB
	3,4 kHz	12 dB
	3,4 kHz	8 dB
	4 kHz	8 dB

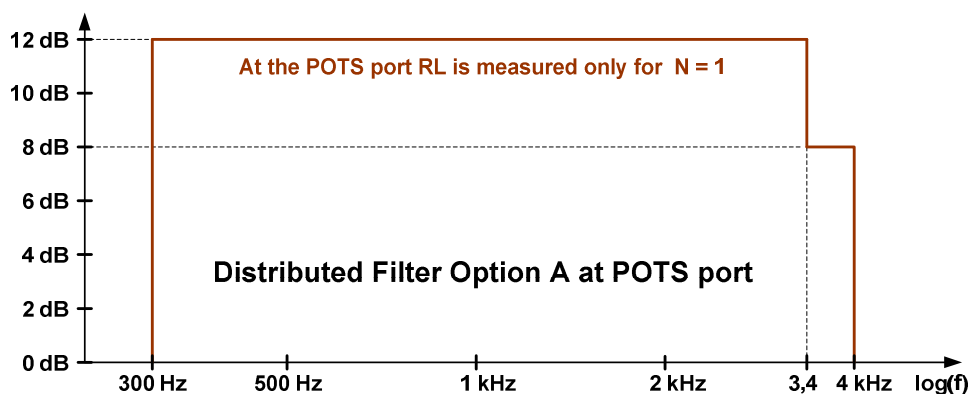


Figure 19: Minimum return loss templates at POTS Port for basic filters with Option A, N = 1

6.6.1.2 Return Loss at the POTS port for Option B

At the POTS port the RL Option B is measured for a single filter only as shown in Table 10 and Figure 20.

Table 10: Return loss requirements, Option B, at the POTS port for all filters

Load & Source Impedance	Frequency	Number of parallel devices
		N = 1
Z_R	300 Hz	14 dB
	500 Hz	18 dB
	2 kHz	18 dB
	3,4 kHz	14 dB

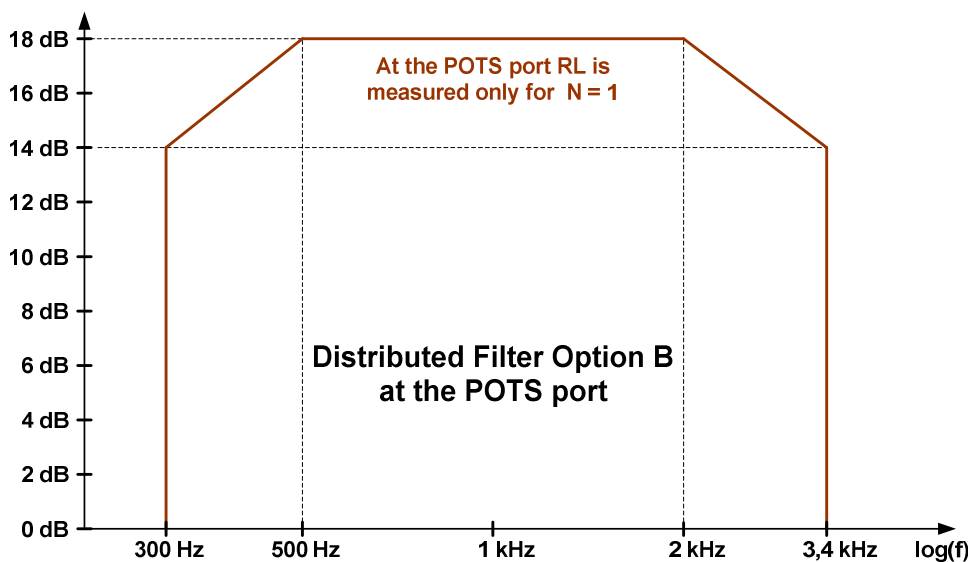


Figure 20: Minimum return loss templates at POTS Port for basic filters with Option B, N = 1

6.6.2 Return Loss requirements at the LINE port Option A

The RL requirements for a single filter at the LINE port are the same as at the POTS port (and also the same as for a central splitter). However, when additional devices are added in parallel, some degradation of the RL is allowed. This degradation is allowed to be worse for the basic filters compared to the standard and the enhanced filters.

6.6.2.1 Return Loss at the Line Port Option A for Basic Filters

The RL requirement at the LINE port for basic filters is specified for N=1 and N=2 in Table 11 and Figure 21.

Table 11: Return loss requirements for basic quality filters, Option A, LINE port testing

Load & Source Impedance	Frequency	Number of parallel devices	
		N = 1	N = 2
Z_R	300 Hz	12 dB	12 dB
	3,4 kHz	12 dB	8 dB
	3,4 kHz	8 dB	8 dB
	4 kHz	8 dB	6 dB

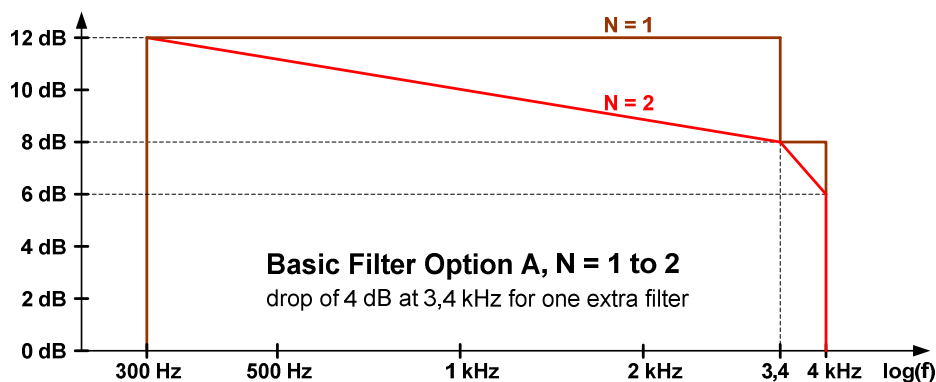


Figure 21: Minimum return loss templates at LINE Port for basic filters with Option A

6.6.2.2 Return Loss at the Line Port Option A for Standard Filters

The RL requirement at LINE port for standard quality filters is specified for N = 1 to 3 in Table 12 and Figure 22.

Table 12: Return loss requirements for standard quality filters, Option A, LINE port testing

Load & Source Impedance	Frequency	Number of parallel devices		
		N = 1	N = 2	N = 3
Z_R	300 Hz	12 dB	12 dB	12 dB
	3,4 kHz	12 dB	10 dB	8 dB
	3,4 kHz	8 dB	8 dB	8 dB
	4 kHz	8 dB	7 dB	6 dB

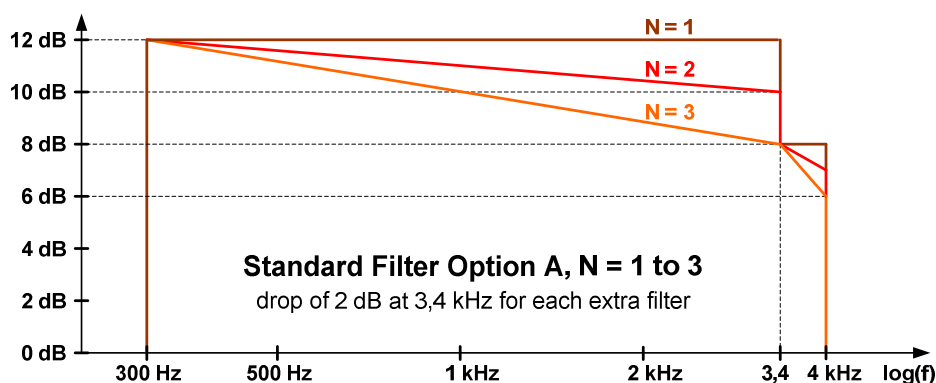


Figure 22: Minimum return loss template at LINE Port for standard filters with Option A

6.6.2.3 Return Loss at the Line Port Option A for Enhanced Filters

The RL requirement at LINE port for enhanced quality filters is specified for N = 1 to 4 in Table 13 and Figure 23.

Table 13: Return loss requirements for enhanced quality filters, Option A, LINE port testing

Load & Source Impedance	Frequency	Number of parallel devices			
		N = 1	N = 2	N = 3	N = 4
Z_R	300 Hz	12 dB	12 dB	12 dB	12 dB
	3,4 kHz	12 dB	11 dB	10 dB	9 dB
	3,4 kHz	8 dB	8 dB	8 dB	8 dB
	4 kHz	8 dB	7,5 dB	7 dB	6,5 dB

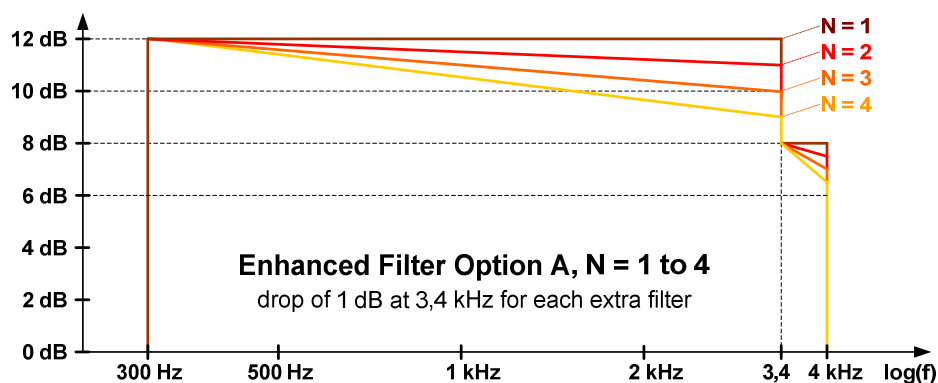


Figure 23: Minimum return loss template at LINE port for enhanced filters with Option A

6.6.3 Return Loss requirements at the LINE port Option B

6.6.3.1 Return Loss at the Line Port Option B for Basic Filters

The RL requirement at LINE port for basic filters is specified for N = 1 and N = 2, as in Table 14 and Figure 24.

Table 14: Return loss requirements for basic quality filters, Option B, LINE port testing

Load & Source Impedance	Frequency	Number of parallel devices	
		N = 1	N = 2
Z_R	300 Hz	14 dB	14 dB
	500 Hz	18 dB	18 dB
	2 kHz	18 dB	14 dB
	3,4 kHz	14 dB	10 dB

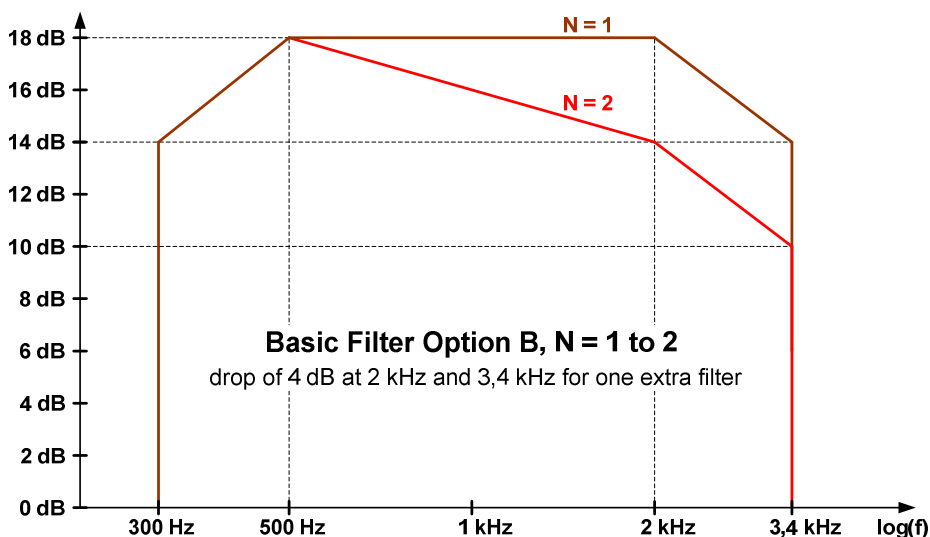


Figure 24: Minimum return loss template at LINE port for Basic Filters with Option B

6.6.3.2 Return Loss at the Line Port Option B for Standard Filters

The RL requirement at LINE port for standard quality filters is specified for N = 1 to 3, as in Table 15 and Figure 25.

Table 15: Return loss requirements for standard quality filters, Option B, LINE port testing

Load & Source Impedance	Frequency	Number of devices in parallel		
		N = 1	N = 2	N = 3
Z_R	300 Hz	14 dB	14 dB	14 dB
	500 Hz	18 dB	18 dB	18 dB
	2 kHz	18 dB	16 dB	14 dB
	3,4 kHz	14 dB	12 dB	10 dB

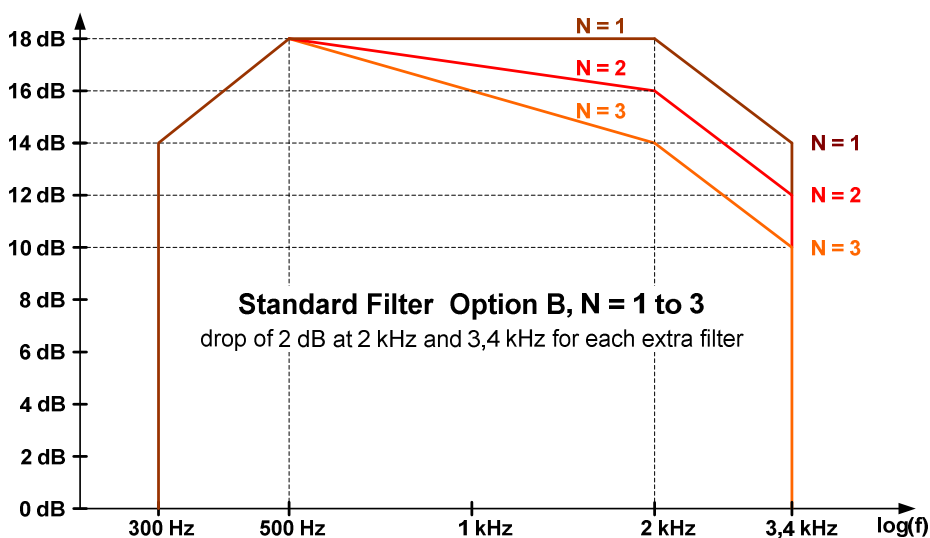


Figure 25: Minimum return loss template at LINE port for Standard Filters with Option B

6.6.3.3 Return Loss at the Line Port Option B for Enhanced Filters

The RL requirement at LINE port for enhanced quality filters is specified for $N = 1$ to 4, as in Table 16 and Figure 26.

Table 16: Return loss requirements for enhanced quality filters, Option B, LINE port testing

Load & Source Impedance	Frequency	Number of parallel devices			
		N = 1	N = 2	N = 3	N = 4
Z_R	300 Hz	14 dB	14 dB	14 dB	14 dB
	500 Hz	18 dB	18 dB	18 dB	18 dB
	2 kHz	18 dB	17 dB	16 dB	15 dB
	3,4 kHz	14 dB	13 dB	12 dB	11 dB

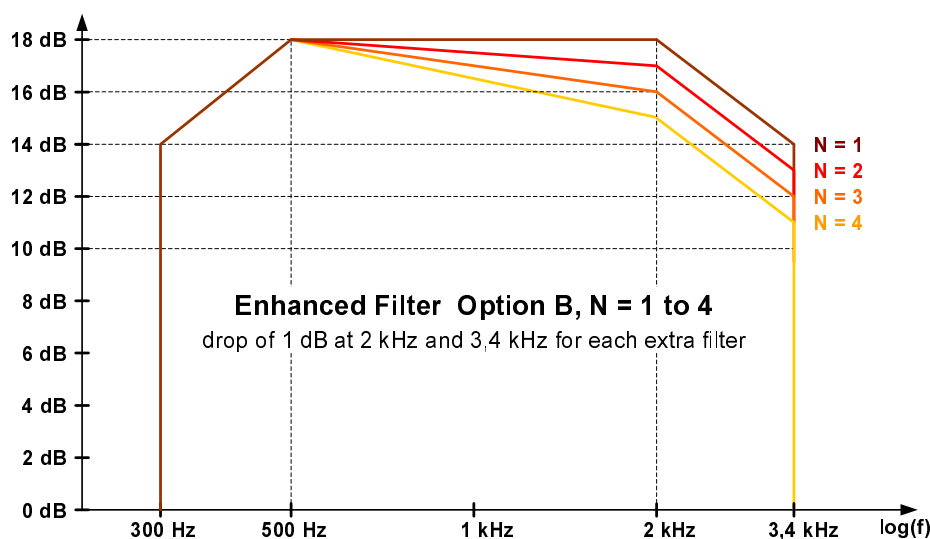


Figure 26: Minimum return loss template at LINE port for Enhanced Filters with Option B

6.7 Requirements relating to metering pulses at 12 kHz or 16 kHz (optional)

The IL_{Meter} measurement is an insertion loss according to [Clause 5.4.2](#) between LINE port and POTS port, which is independent of the direction.

In case pulse metering signals are deployed on the same lines as xDSL, the insertion loss due to the filter (IL_{Meter}) shall be measured at the frequency of the metering pulse. Due to the country specific nature of the rationale of this requirement, the required IL_{Meter} shall be operator specific. A maximum IL_{Meter} requirement in the range of 3 dB to 5 dB should be suitable for many European networks. The Z_{Meter} impedance is defined in [Clause 5.2.8](#).

NOTE 1: A minimum requirement for the IL_{Meter} is not specified.

The $N-1$ parallel filters are left open at their POTS port. The conditions of Table 17 shall be used. This requirement is valid only for the off-hook current condition, with the DC feeding as specified in [Clause 5.1.2](#).

The test result shall be reported for 1 to N devices as specified in the Table 4 (see [Clause 6.4.1](#)), i.e. with the S_{PAR} switch open and closed, and with the S_{DSL} switch closed, i.e. with Z_{DSL} present.

Table 17: Conditions for insertion loss test at 12 kHz or 16 kHz

Level of source voltage	Impedance Z_{source}	Impedance Z_{load}	Impedance Z_{DSL} at the xDSL or LINE port
3,5 V _{RMS} e.m.f.	Z_{Meter} , Clause 5.2.8 (200 Ω)	Z_{Meter} , Clause 5.2.8 (200 Ω)	Z_{DSL} , Clause 5.2.1

NOTE 2: This optional requirement can increase the complexity of the low pass filter implementation.

6.8 Unbalance about Earth

For distributed filters only the unbalance of the low pass part is assessed, and only **a single filter** shall be tested.

The basic test set-up for measuring Unbalance about Earth (UaE) at the POTS port is described in [Clause 5.5](#), as shown in Figures 17 and 18. The test shall be carried out for the conditions described in Table 18 and with switch S1 closed for measurements in the voice band. This requirement is applicable for both the on-hook and the off-hook current condition of the TE. The DC feeding is as specified in [Clause 5.1.2](#).

Table 18: Unbalance about earth, test setups

Test set-up #	Source port to termination port	Measurement port	Frequency range
1: LCL, UaE _{PB} Figure 17	POTS (to LINE)	POTS	50 Hz to 1,1 MHz
2: LCL, UaE _{PB} Figure 18	LINE (to POTS)	LINE	50 Hz to f_{Max} (see note)
3: LCTL Figure 17	POTS (to LINE)	LINE	50 Hz to f_{Max} (see note)
NOTE: f_{Max} is still F.F.S for some xDSL cases; in those cases the frequency range is 50 Hz to f_{H} .			

The xDSL port shall be terminated with a Z_{RefDSL} resistor for all unbalance tests described in the present document. The value of Z_{RefDSL} is dependent on the xDSL variant involved. Specific Z_{RefDSL} values are given in Table A.1 in [Clause A.1](#).

For each of the test set-ups described above, the filter shall meet the unbalance about earth requirements specified in Table 19. The value of f_{L} , f_{H} and f_{Max} in Table 19 is dependent on the xDSL variant involved. Specific frequency values are given in Tables A.5, A.6 and A.7 in [Clause A.2](#).

Table 19: Unbalance about earth, LCL, LCTL, minimum values

Frequency range	State of S1	Value of R	Minimum Unbalance value
50 Hz to 600 Hz	Closed	300 Ω	UaE _{PB} \geq 40 dB
600 Hz to 3 400 Hz	Closed	300 Ω	UaE _{PB} \geq 46 dB
3 400 Hz to 4 000 Hz	Closed	300 Ω	UaE _{PB} \geq 40 dB
4 kHz to f_{L}	Open	$Z_{\text{RefDSL}}/2$	LCL, LCTL \geq 40 dB
f_{L} to f_{H}	Open	$Z_{\text{RefDSL}}/2$	See Clauses A.3 to A.5
f_{H} to f_{Max}	Open	$Z_{\text{RefDSL}}/2$	See Clauses A.3 to A.5

Values of the unbalance in the xDSL band and above it are specified in the Tables A.8 to A.10 in [Clauses A.3 to A.5](#) for each xDSL variant.

6.9 xDSL band requirements

In the xDSL band the POTS noises and transients must be attenuated sufficiently to protect xDSL. Also the POTS circuits must be protected against the strong xDSL signals in the xDSL band and in the transition band, below the xDSL band. Finally the xDSL signals should not be affected by the filter, when they transit from LINE port to xDSL port. The general issues of this protection and separation are described in the informative [Annex I](#).

All IL requirements in the xDSL band are measured according to [Clauses 5.4.3](#) and [5.4.4](#).

NOTE: IL in on-hook and off-hook between POTS port and LINE port is always measured for a single distributed filter, because adding additional filters will only enhance this IL. Parallel distributed filters can affect the xDSL transmission. However this is assessed in [Clause 6.9.4](#) on "xDSL signal loss: IL LINE port to xDSL port" and in [Clause 6.13](#) on Requirements related to POTS transient effects".

6.9.1 xDSL band on-hook isolation between LINE and POTS port

The isolation in the xDSL band on-hook is measured an insertion loss (IL_{DBOnH}) according to [Clause 5.4.3](#), which is independent of the direction.

The source impedance at the LINE side is Z_{RHF} . The filter DUT is terminated with the Z_{OnHI} at the POTS port.

The on-hook DC feeding conditions are specified in [Clause 5.1.2](#).

The test result shall be reported with the S_{PAR} switch open, i.e. for a single device only. The switch S_{DSL} is always closed, because this type of isolation is only needed when DSL equipment is present.

The level of the test signal = -6 dBV emf.

On-hook isolation (IL) for passive distributed filters is not specified. The IL of a single filter shall be measured and reported in the range f_L to f_H .

NOTE: If a passive, static filter achieves the necessary off-hook requirements, this is considered sufficient to achieve also the necessary isolation in on-hook.

6.9.2 xDSL band off-hook isolation between LINE and POTS port

The isolation in the xDSL band off-hook is measured an insertion loss (IL_{DBOffH}) according to [Clause 5.4.3](#), which is independent of the direction.

The source and load impedances at LINE and POTS port are both Z_{RHF} .

This requirement is valid only for the off-hook current condition, with the DC feeding as specified in [Clause 5.1.2](#).

The test result shall be reported with the S_{PAR} switch open, i.e. for a single device only. The switch S_{DSL} is always closed, because this type of isolation is only needed when DSL equipment is present.

The level of the test signal = -6 dBV emf.

6.9.2.1 xDSL band off-hook loss requirements for basic filters

Option A filters: $IL_{DBOffH} > 25$ dB above 32 kHz and $IL_{DBOffH} > 55$ dB above 200 kHz till f_H .

Option B filters: $IL_{DBOffH} > 20$ dB above 32 kHz and $IL_{DBOffH} > 50$ dB above 200 kHz till f_H .

NOTE: For both options IL_{DBOffH} follows a linear interpolation in dB versus a log(frequency) scale in the range 32 kHz to 200 kHz.

6.9.2.2 xDSL band off-hook loss requirements for standard filters

Either of the following two alternative implementations can be chosen and stated by the manufacturer:

- Alternative 1 (better protection of the downstream band): $IL_{DBOffH} > 25$ dB above 32 kHz and $IL_{DBOffH} > 55$ dB above 138 kHz till f_H . Linear interpolation in dB versus a log(frequency) scale in the frequency range 32 kHz to 138 kHz.
- Alternative 2 (better protection of the upstream): $IL_{DBOffH} > 30$ dB above 32 kHz flat up to 200 kHz and $IL_{DBOffH} > 55$ dB above 200 kHz till f_H .

6.9.2.3 xDSL band off-hook loss requirements for enhanced filters

Option A filters: $IL_{\text{DBOffH}} > 45$ dB above 32 kHz flat up to 138 kHz and $IL_{\text{DBOffH}} > 55$ dB above 138 kHz till f_{H} .

Option B filters: $IL_{\text{DBOffH}} > 35$ dB above 32 kHz flat up to 200 kHz and $IL_{\text{DBOffH}} > 55$ dB above 200 kHz till f_{H} .

6.9.3 Transition band signal loss: IL between POTS port and LINE port (optional)

The IL_{TBOffH} measurement is an insertion loss between 25 kHz and 30 kHz according to [Clause 5.4.3](#) between LINE port and POTS port, which is independent of the direction.

The measurement method, the off-hook DC feeding conditions, the number of parallel filters, the presence of Z_{DSL} and the source and load impedances are identical to [Clause 6.9.2](#).

The requirement is optional and values are 25 dB at 25 kHz and 30 dB at 30 kHz.

NOTE: The isolation in the transition band between 25 kHz and 30 kHz can affect the quality of the audio signal particularly in certain sensitive phones at the TE side. Some xDSL transceivers transmit some energy in this band. Although the Transmit PSD of these devices is within the allowed template, the actual xDSL residue signal leaking through the filter causes a relatively high signal in the range 25 kHz to 30 kHz to be present at the POTS port. The non-linearity of some phones converts this residue into an audible noise (e.g. by envelope detection). If the attenuation in the transition band is sufficient, no audible effects are noticeable. Actual test have shown that there exists a threshold effect in these sensitive telephones. This means that the required IL values might be country dependent, depending on the installed base of telephone sets.

6.9.4 xDSL signal loss: IL between LINE port and xDSL port

The Att_{DB} measurement is an insertion loss according to [Clause 5.4.4](#) between LINE port and xDSL port, which is independent of the direction.

The impedance at the LINE side is Z_{RHF} . At the xDSL port the impedance is Z_{DSL} .

The insertion loss requirements are to be met in the case where Z_{LOAD} at the POTS port of Figure 13 or Figure 14 is a short circuit, an open circuit, and the nominal Z_{RHF} impedance defined in [Clause 5.2.3](#). The DC feeding is as specified in [Clause 5.1.2](#).

The requirements of Table 20 are to be met both for a single device and for the case with a total of N parallel devices, depending on the class of the filters as in Table 4 (see under [Clause 6.4.1](#)). As show, the N-1 parallel filters are terminated with an open circuit at their POTS port.

Table 20: Insertion loss between LINE port and xDSL port for distributed filters

Frequency range	Insertion loss between LINE and xDSL port
f_{L} kHz to 50 kHz	-0,5 dB < Att_{DB} < 3 dB
50 kHz to f_{H}	-0,5 dB < Att_{DB} < 1 dB

NOTE: [Annex I](#) contains a description (related to Att_{DB}) how changing impedances at the POTS port may affect the xDSL transmission. The present document recommends the use of TR-127 [i.15] of the Broadband forum to address this issue. See [Annex H](#) on TR-127 [i.15]. The whole TR-127 [i.15] based methodology can be used to prove the effect of parallel distributed filters on xDSL. See also in [Clause 6.13](#).

6.10 Noise

Noise measurements need only to be specified for active/dynamic filters. They are F.F.S. and they are introduced in informative [Annex K](#).

6.10.1 POTS band audible noise level requirements

The psophometric noise power N_{PB} is only measured for active/dynamic filters, as discussed in informative [Annex K](#).

6.10.2 xDSL band noise level

The noise power N_{DB} is only measured for active/dynamic filters, as discussed in informative [Annex K](#).

6.11 Distortion

6.11.1 POTS band intermodulation distortion (optional)

The test set-up to measure POTS band intermodulation distortion (IMD_{PB}) is given in Figure 11 with the switches S_1 and S_2 in position 1 with only one distributed filter (DUT) connected ($N = 1$), i.e. S_{PAR} is open. This requirement shall be met with the switch S_{DSL} in Figure 11 both open and closed. Both the source and load impedance used shall be equivalent to Z_R . This requirement shall be met for both the on-hook and off-hook conditions of the TE. The DC feeding conditions are given in [Clause 5.1.2](#).

The test signal to be used is as according to ITU-T Recommendation O.42 [2].

Using the 4-tone method [2] at a level of -9 dBV, the second and third order harmonic distortion products shall be at least 57 dB and 60 dB, respectively below the received signal level.

The second and third order harmonics of the 4-tone signal are measured at POTS port.

NOTE 1: In the on-hook condition the POTS impedance at the LE side is Z_R , while at the TE side we have either Z_{OnHI} or Z_{OnLI} . In order to simplify the test set-up, it is accepted that the intermodulation test in on-hook is performed from a Z_R source to a Z_R load.

NOTE 2: A methodology for performing this IMD test in the presence of an xDSL signal is available in [i.3] and [i.5]. It was thought that this represents a more realistic scenario for IMD evaluation. However, this is doubtful. The TR-127 [i.15] based methodology presented in the [Clause 6.11.2](#) is considered a more recommendable approach to the test of splitter or distributed filter distortion in the presence of POTS and xDSL signals.

NOTE 3: This POTS band IMD test is relatively difficult to perform, particularly in the presence of DC feeding conditions. There is no proof that this test is either necessary or sufficient. If a central splitter or distributed filter passes the TR-127 [i.15] tests this proves more about its intrinsic qualities than achieving the IMD_{PB} .

6.11.2 DSL band intermodulation distortion (optional)

For testing the xDSL distortion of a central splitter or distributed filter, the methodology developed by the Broadband Forum (TR-127 [i.15]) is adopted. The TR-127 [i.15] is published by the Broadband Forum. The test is described in informative [Annex H](#).

NOTE: As the Broadband Forum methodology is now finalized and replicated with sufficient consistency, ETSI recommends TR-127 [i.15] to test IMD_{DB} in the xDSL band.

These optional tests (if required by the operator) will be based on stationary tests within TR-127 [i.15]. This requires 5 tests in sections 8.2 to 8.6 plus the section 8.10 of the TR-127 [i.15] to be executed. The following ETSI proprietary adaptations of the testing requirements are suggested: the line lengths specified in section 8.1.2 of TR-127 [i.15] for ADSL will be augmented with one extra maximum length of 4,2 km.

The requirements for the tests 8.4 and 8.6 with central splitters or distributed filters as DUT will be identical as in the TR-127 [i.15]. (The tests 8.2, 8.3, 8.5 are calibrations and baseline tests, with no DUT present.)

For the test in section 8.10 of TR-127 [i.15], the drop in capacity allowed for the maximal length is maximally 30 %.

6.12 Group delay distortion

The increase of the group delay distortion resulting from the insertion of one filter shall be measured in the frequency range 300 Hz to 4 kHz. The increase shall comply with the limits specified in Table 21.

Table 21: Group delay distortion, maximum values

Frequency range	Maximum value
200 Hz to 600 Hz	250 μ s
600 Hz to 3 200 Hz	200 μ s
3 200 Hz to 4 000 Hz	250 μ s

Two tests shall be performed, which each shall use identical signal source and load impedances. A first test is carried out with impedances of 600 Ω , a second test with Z_R as impedances. The level of the test signal is -10 dBV.

The set-up for measuring group delay distortion is given in Figure 11, and **limited to a single filter**, i.e. with the switch S_{PAR} open. This requirement shall be met with the switch S_{DSL} in Figure 11 both open and closed. The DC feeding current is specified in [Clause 5.1.2](#). This requirement shall be met for both the on-hook and off-hook current conditions.

NOTE: In the on-hook condition the POTS impedance at the LE side is Z_R , while at the TE side we have either Z_{OnHI} or Z_{OnLI} . In order to simplify the test set-up, it is accepted that the group delay test in on-hook is performed from a Z_R source to a Z_R load.

6.13 Requirements related to POTS transient effects (optional)

A POTS transient test existed in previous versions of the present document, published as TS 101 952-1-5 [i.16] and intended to test how the transient signals caused by POTS affect the xDSL system. Such a test is extremely useful. However, the validity of the associated test method was unsatisfactory and therefore the **old** test method was removed completely.

Recently a new approach to transient testing was published by in the Broadband Forum. The Broadband Forum document Technical Requirement 127 (TR-127) [i.15] describes this methodology, which consists in testing the central splitters or distributed filters on a real line, with two baseline xDSL modems and with the injection of POTS LE signals (POTS AC, POTS DC, ringing, ...) including POTS TE transients, such as off-hook and ring-trip.

Therefore, for all transitional tests of central splitters and distributed filters under POTS transients, it is recommended that the TR-127 methodology be used.

These optional tests (if required by the operator) will be based on transitional tests within TR-127 [i.15]. This requires calibration and baseline tests 8.2, 8.3 and 8.5, and DUT checks according to sections 8.7 to 8.9 of the TR-127 [i.15] to be executed. (Tests in TR-127 [i.15] 8.4 and 8.6 are static tests, and their use is related to other splitter properties.)

NOTE: The following ETSI proprietary adaptations of the testing requirements is still F.F.S.: in line with the [Clause 6.11.2](#) the line lengths specified in section 8.1.2 of TR-127 [i.15] for ADSL might be augmented with one extra maximum length of 4,2 km.

Annex A (normative): Particular requirements for passive distributed filters

A.1 Z_{DSL} and Z_{RefDSL} for specific xDSL over POTS variants

In many of the tests, the xDSL port of the central splitter or the distributed filter is terminated with impedances called Z_{DSL} and Z_{RefDSL} . Their purpose is explained in [Clause 5.2.1](#).

A.1.1 Generic definition of Z_{DSL} , using Z_{RefDSL} , C_{DSL} and L_{DSL}

Z_{DSL} is an impedance, connected as a termination at the xDSL port of the central splitter or distributed filter. This impedance is a high pass filter (HPF). For xDSL over POTS, the different variants of Z_{DSL} , as defined in [Clause 5.2.1](#), are composed of Z_{RefDSL} , C_{DSL} , and L_{DSL} , which results in the equivalent circuit of Figure A.1. The values of the elements in Z_{DSL} are compiled in Table A.1.

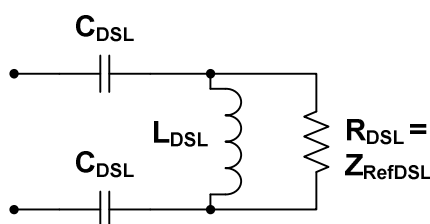


Figure A.1: Equivalent schematic of the Z_{DSL} HPF impedance model

Contrary with central splitter, for distributed splitters there is only one Z_{DSL} variant, because, there is never a high pass filter inside the distributed filter (see Figure 2).

Z_{RefDSL} is the design impedance of the xDSL transceivers of a specific xDSL variant, and is a resistor independent of the used frequency range. In practice the Z_{RefDSL} is purely resistive, and the symbol R_{DSL} is used as its equivalent.

L_{DSL} depends on the lower edge of the pass band of the xDSL, and matches also the Z_{RefDSL} ($\equiv R_{\text{DSL}}$) of the xDSL at that lower edge.

The C_{DSL} depends also on the pass band of the xDSL.

The impedance of Z_{DSL} is the same as the impedance seen at the LINE port towards the xDSL port for the POTS central splitter, as explained in part 1 of the present document, TS 101 952-1 [11]. In this way the total impedance of the xDSL transceiver found at the LINE port has always the same value for a POTS central splitter and for the distributed filters.

NOTE: Some contributions studied the order of the Z_{DSL} HPF impedance model. As alternative to the second order variant (above), it was proposed to allow a third order filter. However, no consensus could be reached on this. Therefore, only the second order Z_{DSL} is defined and in use.

To simplify the measurements above 1 MHz, the source or load termination with Z_{DSL} can be replaced by $Z_{\text{RefDSL}} \equiv R_{\text{DSL}}$, i.e. the coil L_{DSL} and the capacitors C_{DSL} are removed. If needed, DC blocking capacitors (with an appropriate value) can still be included, to prevent DC current to flow in R_{DSL} ($\equiv Z_{\text{RefDSL}}$). This is applicable when the R_{DSL} would not sustain any DC current, or when the DC current should follow another desirable path in the test set-up.

Table A.1: Values of elements of Z_{DSL} for different xDSL system variants

Impedance name	ADSL over POTS (mandatory)	ADSL2plus over POTS (mandatory)	European VDSL1 over POTS starting at 25 kHz	European VDSL1 over POTS starting at other frequencies (see note)	VDSL2 over POTS including the US0 band from 25 kHz	VDSL2 over POTS not including the US0 band (see note)
$Z_{RefDSL} \equiv R_{DSL}$	100 Ω	100 Ω	135 Ω	135 Ω	100 Ω	100 Ω
L_{DSL}	0,470 mH	0,470 mH	0,634 mH	not specified	0,470 mH	F.F.S.
C_{DSL}	54 nF	54 nF	40 nF	not specified	54 nF	F.F.S.

NOTE: There are VDSL1 and VDSL2 variants over POTS, with a lower frequency edge of the used frequency band higher than 25 kHz. These VDSL transceivers might have a high pass with a higher cut-off frequency.

A.1.2 Z_{DSL} for ADSL over POTS

For distributed filters the impedance model of Figure A.2 shall be used to terminate the xDSL port of the distributed filter.

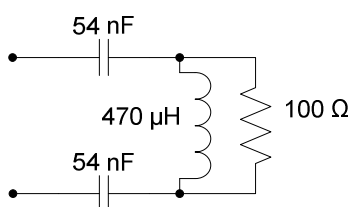


Figure A.2: Schematic diagram of the impedance Z_{DSL} for ADSL over POTS

A.1.3 Z_{DSL} for European VDSL1 over POTS, with US0 starting at 25 kHz

For European VDSL1 over POTS starting at 25 kHz the impedance model of Figure A.3 shall be used to terminate the xDSL port of the distributed filter.

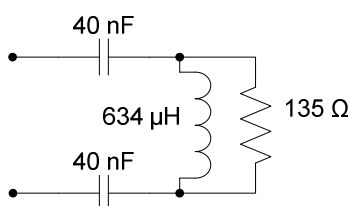


Figure A.3: Schematic diagram of the impedance Z_{DSL} for European VDSL1 over POTS, starting at 25 kHz

A.1.4 Z_{DSL} for VDSL2 over POTS with US0

For this VDSL2 variant, the impedance models are **identical** to the ADSL over POTS impedance model in [Clause A.1.2](#).

NOTE: The harmonization of the Z_{DSL} for VDSL2 with ADSL and its variants was established in the ITU-T.

A.2 Common requirements for passive distributed filters

A complete overview of all common requirements for xDSL over POTS is listed in the Table A.2. Symbols are explained in [Clause 3.2](#). The specific frequency ranges for the individual xDSL types are compiled in additional Tables A.5 to A.7.

Table A.2: Dedicated requirements for distributed filters for xDSL system variants

Clause number	Symbol	Frequency Range	Filters over POTS for xDSL	BASIC	STANDARD	ENHANCED
				Number of parallel filters		
6.2.1	R_{AtoB}	DC	$> 5 \text{ M}\Omega$	1	1	1
6.2.2	R_{DC}	DC	$< 50 \Omega$	1	1	1
6.3.1	V_{RD}	25 Hz and/or 50 Hz	$< 2 V_{RMS}$ (source e.m.f. $35 V_{RMS}$)	1	1	1
6.3.2	Z_{InRing}	25 Hz and/or 50 Hz	$> 40 \text{ k}\Omega$ (25 Hz); $> 36 \text{ k}\Omega$ (50 Hz)	1	1	1
6.3.3	THD_{Ring}	25 Hz and/or 50 Hz	$< 10 \%$	1	1	1
6.4.1	IL_{PBOnH}	200 Hz to 2,8 kHz	$\pm 4 \text{ dB}$	1 to 2	1 to 3	1 to 4
6.4.2	IL_{MaxOnH}	200 Hz to 2,8 kHz	See clause or Table A.3	1	1	1
	IL_{VarOnH}	200 Hz to 2,8 kHz	See clause or Table A.3	1	1	1
6.5	$IL_{MaxOffH}$	200 Hz to 4 kHz	See clause or Table A.3	1 to 2	1 to 3	1 to 4
	$IL_{VarOffH}$	200 Hz to 4 kHz	See clause or Table A.3	1 to 2	1 to 3	1 to 4
6.6.1	RL_{PP} POTS port	300 Hz to 4 kHz Opt A or 300 Hz to 3,4 kHz Opt B	See clause or Table A.3 and Figure A.4	1	1	1
6.6.2	RL_{LP} LINE port	Option A: 300 Hz to 4 kHz	See clause or Table A.3 and Figure A.4	1 to 2	1 to 3	1 to 4
6.6.3	RL_{LP} LINE port	Option B: 300 Hz to 3,4 kHz				
6.7	IL_{Meter}	12 kHz and 16 kHz	Optional ($< 5 \text{ dB}$ suggested)	1 to 2	1 to 3	1 to 4
6.8	Ua_{EPB}	50 Hz to 600 Hz	$> 40 \text{ dB}$			
		600 Hz to 3,4 kHz	$> 46 \text{ dB}$	1	1	1
		3,4 kHz to 4 kHz	$> 40 \text{ dB}$			
	LCL LCTL	DSL band	Balance differs depending on the xDSL variant, see Tables A.8 to A.10	1	1	1
6.9.1	IL_{DBOnH}	f_L to f_H	Not specified, only reported	1	1	1
6.9.2	IL_{DBOffH}	DSL band	See clause or Table A.4	1	1	1
6.9.3	IL_{TBOffH}	20 kHz to f_L	Optional; only in off-hook	1	1	1
6.9.4	Att_{DB}	f_L to 50 kHz	$-0,5 \text{ dB} < Att_{DB} < 3 \text{ dB}$	1 to 2	1 to 3	1 to 4
		50 kHz to f_H	$-0,5 \text{ dB} < Att_{DB} < 1 \text{ dB}$			
6.10.1	N_{PB}	200 Hz to 4 kHz	N.A. for passive filters	1	1	1
6.10.2	N_{DB}	f_L to f_H	N.A. for passive filters	1	1	1
6.11.1	IMD_{PB}	POTS band	Optional; see requirement in the clause	1	1	1
6.11.2	IMD_{DB}	DSL band	Optional; use of TR-127 of BB-Forum	1	1	1
6.12	Group Delay	200 Hz to 600 Hz 600 Hz to 3,2 kHz 3,2 kHz to 4 kHz	$< 250 \mu\text{s}$ $< 200 \mu\text{s}$ $< 250 \mu\text{s}$	1	1	1
6.13	Transients	POTS and xDSL band	Optional; use of TR-127 [i.15] of BB-Forum	1 to 2	1 to 3	1 to 4

Table A.3 merges all POTS band requirements, for basic, standard and enhanced filters and for all values of N (1 to 2 for basic filters, 1 to 3 for standard filters and 1 to 4 for enhanced filters).

Table A.3: Overview of all POTS band requirements for all types of filters and N values.

POTS band	BASIC		STANDARD			ENHANCED			
On-Hook Insertion Loss High Impedance; see Clause 6.4.1									
Frequency	N = 1	N = 2	N = 1	N = 2	N = 3	N = 1	N = 2	N = 3	N = 4
200 Hz to 2,8 kHz	± 4 dB	± 4 dB	± 4 dB	± 4 dB	± 4 dB	± 4 dB	± 4 dB	± 4 dB	± 4 dB
On-Hook IL Low Impedance: Maximum IL & IL Variation; see Clause 6.4.2									
Frequency	N = 1	(N = 2)	N = 1	(N = 2)	(N = 3)	N = 1	(N = 2)	(N = 3)	(N = 4)
200 Hz to 2,8 kHz	2,5 dB	N.A.	2 dB	N.A.	N.A.	2 dB	N.A.	N.A.	N.A.
Off-Hook Insertion Loss: Maximum IL and IL Variation; see Clause 6.5									
Frequency	N = 1	N = 2	N = 1	N = 2	N = 3	N = 1	N = 2	N = 3	N = 4
200 Hz to 4 kHz	2,5 dB	3 dB	2 dB	2,5 dB	3 dB	2 dB	2,25 dB	2,5 dB	3 dB
Return Loss Off-Hook at POTS Port Option A; see Clause 6.6.1.1									
Frequency	N = 1	(N = 2)	N = 1	(N = 2)	(N = 3)	N = 1	(N = 2)	(N = 3)	(N = 4)
300 Hz	12 dB	N.A.	12 dB	N.A.	N.A.	12 dB	N.A.	N.A.	N.A.
3,4 kHz	12 dB	N.A.	12 dB	N.A.	N.A.	12 dB	N.A.	N.A.	N.A.
3,4 kHz	8 dB	N.A.	8 dB	N.A.	N.A.	8 dB	N.A.	N.A.	N.A.
4 kHz	8 dB	N.A.	8 dB	N.A.	N.A.	8 dB	N.A.	N.A.	N.A.
Return Loss Off-Hook at POTS Port Option B; see Clause 6.6.1.2									
Frequency	N = 1	(N = 2)	N = 1	(N = 2)	(N = 3)	N = 1	(N = 2)	(N = 3)	(N = 4)
300 Hz	14 dB	N.A.	14 dB	N.A.	N.A.	14 dB	N.A.	N.A.	N.A.
500 Hz	18 dB	N.A.	18 dB	N.A.	N.A.	18 dB	N.A.	N.A.	N.A.
2 kHz	18 dB	N.A.	18 dB	N.A.	N.A.	18 dB	N.A.	N.A.	N.A.
3,4 kHz	14 dB	N.A.	14 dB	N.A.	N.A.	14 dB	N.A.	N.A.	N.A.
Return Loss Off-Hook at LINE Port Option A; see Clause 6.6.2									
Frequency	N = 1	N = 2	N = 1	N = 2	N = 3	N = 1	N = 2	N = 3	N = 4
300 Hz	12 dB	12 dB	12 dB	12 dB	12 dB	12 dB	12 dB	12 dB	12 dB
3,4 kHz	12 dB	8 dB	12 dB	10 dB	8 dB	12 dB	11 dB	10 dB	9 dB
3,4 kHz	8 dB	8 dB	8 dB	8 dB	8 dB	8 dB	8 dB	8 dB	8 dB
4 kHz	8 dB	6 dB	8 dB	7 dB	6 dB	8 dB	7,5 dB	7 dB	6,5 dB
Return Loss Off-Hook at LINE Port Option B; see Clause 6.6.3									
Frequency	N = 1	N = 2	N = 1	N = 2	N = 3	N = 1	N = 2	N = 3	N = 4
300 Hz	14 dB	14 dB	14 dB	14 dB	14 dB	14 dB	14 dB	14 dB	14 dB
500 Hz	18 dB	18 dB	18 dB	18 dB	18 dB	18 dB	18 dB	18 dB	18 dB
2 kHz	18 dB	14 dB	18 dB	16 dB	14 dB	18 dB	17 dB	16 dB	15 dB
3,4 kHz	14 dB	10 dB	14 dB	12 dB	10 dB	14 dB	13 dB	12 dB	11 dB

Figure A.4 merges all templates for Return Loss at the LINE port, both Option A and B, for basic, standard and enhanced filters and for all values of N (1 to 2 for basic filters, 1 to 3 for standard filters and 1 to 4 for enhanced filters).

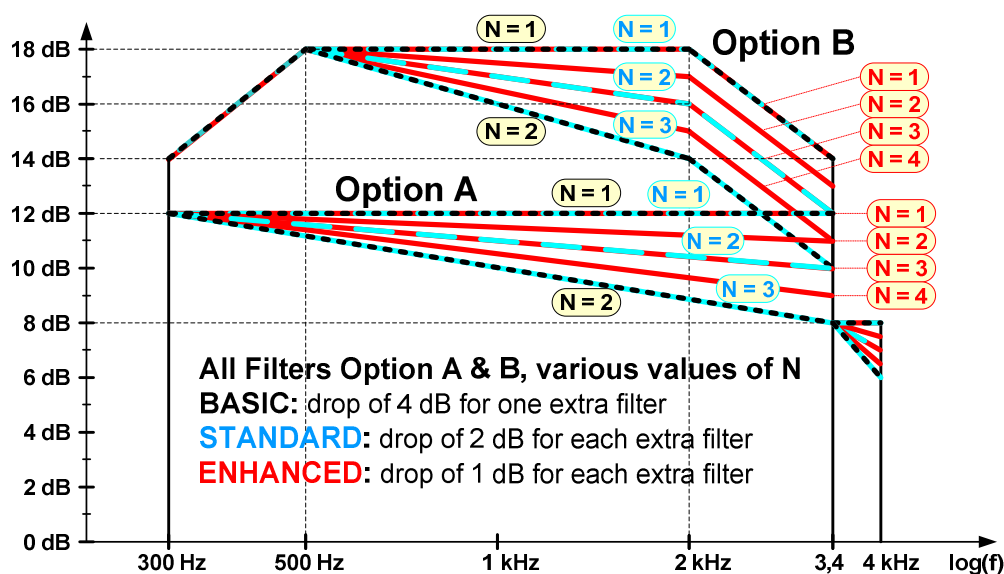


Figure A.4: All RL templates at LINE port for all filters types Option A & B, and all required N values

Table A.4: Overview of Insertion Loss in the xDSL band for all types of filters

BASIC 6.9.2.1	Option A		Option B	
Frequency	32 kHz	200 kHz	32 kHz	200 kHz
Insertion Loss xDSL band	25 dB ^L (See note 1)	55 dB	20 dB ^L (See note 1)	50 dB
STANDARD 6.9.2.2	Alternative 1 (better protection of downstream)		Alternative 2 (better protection of upstream)	
Frequency	32 kHz	138 kHz	32 kHz	200 kHz
Insertion Loss xDSL band	25 dB ^L (See note 1)	55 dB	30 dB ^F (See note 2)	55 dB
ENHANCED 6.9.2.3	Option A		Option B	
Frequency	32 kHz	138 kHz	32 kHz	200 kHz
Insertion Loss xDSL band	45 dB ^F (See note 2)	55 dB	35 dB ^F (See note 2)	55 dB

NOTE 1: ^L = Linear interpolation to the next frequency.
NOTE 2: ^F = Flat extension to the next frequency.

Table A.5: Dedicated frequency ranges for distributed filters for ADSL system variants

Frequency Symbol	ADSL or ADSL2 over POTS: ITU-T Recommendation G.992.1 [i.9], Annex A or ITU-T Recommendation G.992.3 [i.10], Annex A or M	ADSL2plus over POTS: ITU-T Recommendation G.992.5 [i.11], Annex A or M
f_L	32 kHz	32 kHz
f_{M1}	138 kHz	138 kHz
f_H	1 104 kHz	2 208 Hz
f_{Max}	5 MHz	5 MHz

Table A.6: Dedicated frequency ranges for distributed filters for VDSL1 system variants

Frequency Symbol	Filters for VDSL1 over POTS ITU-T Recommendation G.993.1 [i.12] with US0 band (i.e. starting at 25 kHz)	Filters VDSL 1 over POTS for ITU-T Recommendation G.993.1 [i.12] without US0 band or starting at 138 kHz or higher
f_L	32 kHz	Lowest used VDSL1 frequency
f_{M1}	138 kHz	Highest of 138 kHz and lowest used VDSL1 frequency
f_H	12 MHz	12 MHz
f_{Max}	F.F.S.	F.F.S.

Table A.7: Dedicated frequency ranges for distributed filters for VDSL2 system variants

Frequency Symbol	Filters for VDSL2 over POTS ITU-T Recommendation G.993.2 [i.13] with US0 band type A or M (starting at 25 kHz)	Filters VDSL2 over POTS ITU-T Recommendation G.993.2 [i.13] without US0 band or starting at 138 kHz or higher
f_L	32 kHz	Lowest used VDSL2 frequency
f_{M1}	138 kHz	Highest of 138 kHz and lowest used VDSL2 frequency
f_H	30 MHz	30 MHz
f_{Max}	F.F.S.	F.F.S.

A.3 Specific requirements for passive filters for ADSL over POTS variants

Specific requirements limited to passive filters for ADSL over POTS are listed in the Table A.8. Symbols are explained in [Clause 3.2](#). Frequency values dedicated to ADSL are in Table A.5.

Table A.8: Dedicated requirements for passive filters for ADSL over POTS variants at both the LE and the TE side

Clause number	Symbol	Frequency Range	Filters over POTS for ADSL, ADSL2 or ADSL2plus
Clause 6.8 low pass	$LCL_{POTSport}$	4 kHz to f_L f_L to 1,1 MHz	> 40 dB > 40 dB
Clause 6.8 low pass	$LCTL_{POTStoLINE}$ or $LCL_{LINEport}$	4 kHz to f_L f_L to f_H f_H to f_{Max}	> 40 dB > 40 dB > 30 dB

A.4 Specific requirements for passive filters for VDSL1 over POTS variants

Specific requirements limited to passive filters for VDSL1 over POTS are listed in the Table A.9. Symbols are explained in [Clause 3.2](#). Frequency values dedicated to VDSL1 are in Table A.6. Examples of VDSL1 over POTS starting well above 32 kHz could be a VDSL at the cabinet, possibly in parallel with ADSL from the LE.

Table A.9: Dedicated requirements for passive filters for VDSL1 over POTS variants

Clause number	Symbol	Frequency Range	Filters for VDSL1 over POTS for any f_L
Clause 6.8 low pass	$LCL_{POTSport}$	4 kHz to f_L f_L to 1,1 MHz	> 40 dB > 40 dB
Clause 6.8 low pass	$LCTL_{POTStoLINE}$ or $LCL_{LINEport}$	4 kHz to f_L f_L to f_H f_H to f_{Max}	> 40 dB > 40 dB > 30 dB

A.5 Specific requirements for passive filters for VDSL2 over POTS variants

Specific requirements limited to passive filters for VDSL2 over POTS are listed in the Table A.10. Symbols are explained in [Clause 3.2](#). Frequency values dedicated to VDSL2 are in Table A.7.

Table A.10: Dedicated requirements for passive filters for VDSL2 over POTS variants

Clause number	Symbol	Frequency Range	Filters for VDSL2 over POTS for any f_L
Clause 6.8 low pass	$LCL_{POTSport}$	4 kHz to f_L f_L to 1,1 MHz	> 40 dB > 40 dB
Clause 6.8 low pass	$LCTL_{POTStoLINE}$ or $LCL_{LINEport}$	4 kHz to f_L f_L to 2,2 MHz 2,2 to 12 MHz 12 MHz to f_H f_H to f_{Max}	> 40 dB > 40 dB > 40 dB Drop 20 dB/decade from 40 dB at 12 MHz > 30 dB

Annex B (informative): Evolution of the documents

This annex should explain the old organization of the splitter and filter documents. However, the **general description** appears only in part 1 of the new documents. All other parts point to the informative Annex B in part 1. Thus refer to TS 101 952-1 [11], which contains an Annex B with the same title and the necessary content.

Related to the present document the following **additional information** is useful:

- 1) The earliest version of the present document, numbered according the older numbering scheme, as TS 101 952-1-5 [i.16] (V1.1.1), was published in April 2003. However, it was virtually impossible to build a distributed filter at reasonable complexity according to that version of document, because it imposed central splitter quality on a distributed filter device as the only option. Therefore, a rework of that document was needed.
- 2) The subsequent version of the document was published in October 2006, also numbered according the older scheme, as TS 101 952-1-5 [i.17] (V1.2.1). This published version contains only a minimal set of tests. Indeed, **severe limitations** can be noticed in this V1.2.1 version:
 - a) The V.1.2.1 version does not impose a minimal requirement for the combined effect of multiple distributed filters, except that the input impedance of the distributed filter is required to be larger than the impedance of a 27 nF capacitor in the POTS band.
 - b) The V1.2.1 version is testing a distributed filter, assuming in many instances that it is the only device at the customer's premises. This means that some of the tests in the V1.2.1 version are imposed only on a single distributed filter, and the detrimental effect of adding additional distributed filters in parallel are ignored, i.e. it is not imposed to measure it and/or to report it.
 - c) In other cases it seems that tests are imposed on a group of distributed filters, i.e. on a single distributed filter under tests, with N-1 other distributed filters of the same type in parallel, but in the on-hook mode. However, if one checks the requirements in the V1.2.1 version, one will notice that the requirements only test the additional or incremental effect of a single distributed filter as device under test, and ignore the total effect of all filters in parallel. The incremental effect of a single distributed filter seems acceptable, but the cumulative effect, which can be unacceptably bad, is not reported. (See also the tutorial in [Clause C.1.](#))
 - d) The previous version of the document also incorrectly ignored the effect of the Z_{DSL} on the distributed filter performance, a requirement which is imposed on all regular central splitters. The insertion loss of the distributed filter measured without the insertion loss of the input impedance of the ADSL modem largely underestimates the actual effect of the complete DSL installation on the POTS signal.

Therefore, (as also stated in note 5 of the [Foreword](#)) we should warn operators and the users that the deployment of multiple distributed filters that only fulfil the previous published requirement (TS 101 952-1-5 [i.16] (V1.2.1)) can (and very likely will) result in degradation of the quality the phone signals and potentially of the DSL signals.

Annex C (informative): Correlation and trade-offs between filter requirements

The information in this annex is for information only, and does not constitute a requirement for distributed filters. The examples are taken from potentially simplified simulations, to show certain issues. Actual designs cannot be required to achieve the simplified and partial results shown in this annex.

TRADE-OFFS: This informative annex contains a number of examples of how POTS band requirements and xDSL band requirements of filters are correlating. Similarly there is a quality drop when installing parallel distributed filters. Furthermore, when a filter is build to have a strong rejection in the xDSL band, it often will have issues when parallel filters are used.

There are several correlations between the requirements of distributed filters. These trade-offs are unavoidable to limit the complexity of the filters. In [Clause 6.1.7](#) the following list of trade-offs was introduced, which is expanded here:

- POTS band requirements for filters (and splitters) are inversely linked with the IL in the xDSL band.
 - To improve the IL and RL requirements for a single device in the POTS band (e.g. to achieve option B), the IL in the xDSL band needs to be weaker, or the complexity should be higher. If the RL (i.e. in the POTS band) has to be good (Option B) then the IL in the xDSL band often is not as tight as when an Option A is allowed in the POTS band, which can achieve a stronger xDSL band result.
- POTS band requirements achieved by a single filter will degrade when multiple devices are put in parallel.
 - To minimize the quality losses in the POTS band, i.e. IL and RL, when parallel devices are deployed, the IL in the xDSL band also needs to be weaker.
 - Filters that are optimized as a single device with the best possible IL in the xDSL band, with no margin for the RL and the IL in the POTS band, will suffer greatly in the POTS band when parallel devices are deployed. This means that a filter can be very good on its own, with an option B RL and a good IL in the POTS band, and superb IL in the xDSL band. However, such filter has likely a large input capacitance and this will then reduce the quality in the POTS band substantially, when parallel filters are put in use.
- Higher complexity is needed to achieve better POTS band and xDSL band properties, particularly when large numbers of parallel filter devices are installed, while attempting to keep a quality close to a master splitter.
 - Keeping high quality RL (and IL) in the POTS band, even for 3 or 4 parallel devices, combined with a strong rejection in the xDSL band will not be possible with a basic or a standard filter, but will likely require enhanced quality filters, unless a substantial reduction of the IL in the xDSL band is allowed.

Besides trade-offs between requirements in POTS and xDSL band related to the use of parallel filters, there is also a different effect on the RL at the POTS port and the LINE port of the filter:

- Installing multiple parallel filters causes different RL effects at the POTS port and at the LINE port.

Finally there are RL issues that differ between POTS and LINE port, when the xDSL transmitters are removed:

- There is also a different effect on the RL at POTS and LINE port when the xDSL transmitters are removed, while the filters are kept in the installation.
 - When the xDSL transmitters are removed, i.e. when the xDSL service is uninstalled, sometimes the filters are kept in the installation by mistake, which might happen unintentionally. This will affect the RL in the POTS band, but often differently at POTS and LINE port.

C.1 Detrimental effect of parallel distributed filters

At the LINE port the central splitter or a single distributed filter represents a capacitance in the POTS band. Each additional distributed filter will increase that capacitance. The detrimental effect of the capacitance of a single distributed filter will affect the IL of the POTS transmission, always tending to degrade the IL measurement. Furthermore, when multiple filters are put in parallel, the IL will tend to degrade even more.

For RL the insertion of the capacitance of a single distributed filter is not always causing degradation. Occasionally a single distributed filter can slightly improve the RL at e.g. the LINE or the POTS port. Even a second filter might still improve the RL over part of the POTS band or even the whole POTS band. However, ultimately multiple filters will degrade the IL in the POTS band at all ports of the filter over the whole band.

The following Figures are examples from simulations that show how IL and the RL degrade or change when one filter is present and when more filters (identical) are put in parallel. The example is simulated with a "Standard Filter", with 2 transformers or 4 coils. The filters used all have an input capacitance that is quite high, in fact too high to allow more than two distributed filters to be used in parallel. However, this causes their IL in the DSL band to be superior (see Figure C.4). Note also that the RL templates are the requirements for a single distributed filter.

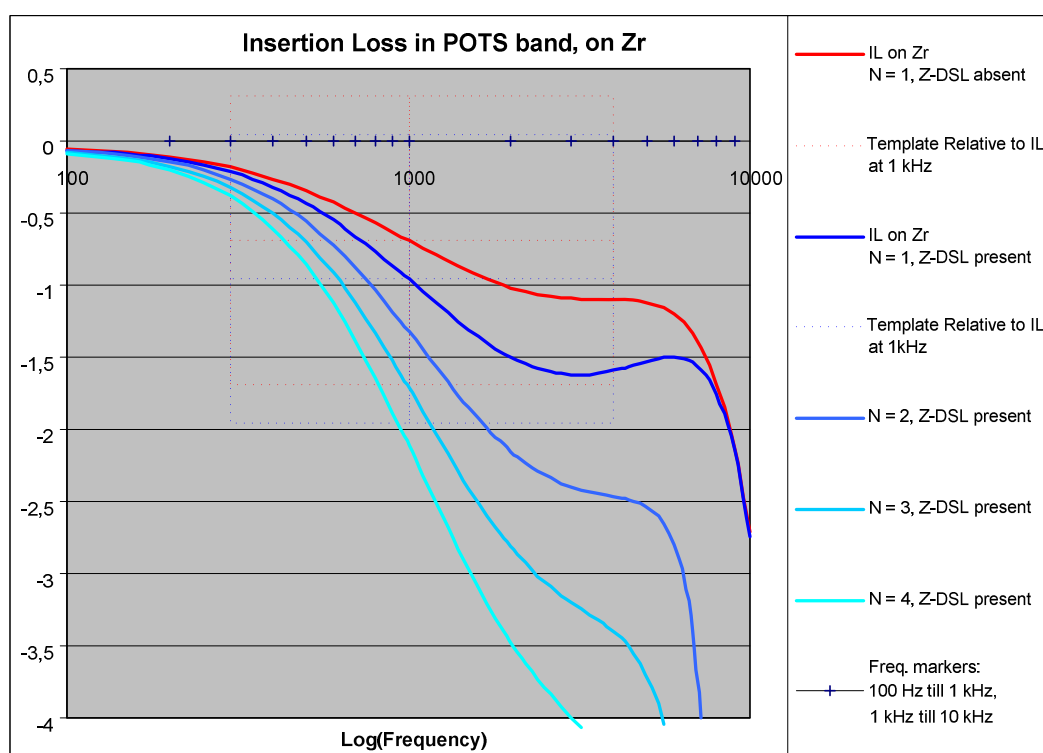


Figure C.1: Effect of 1 to 4 distributed filters on the Insert Loss between LINE port ant POTS port

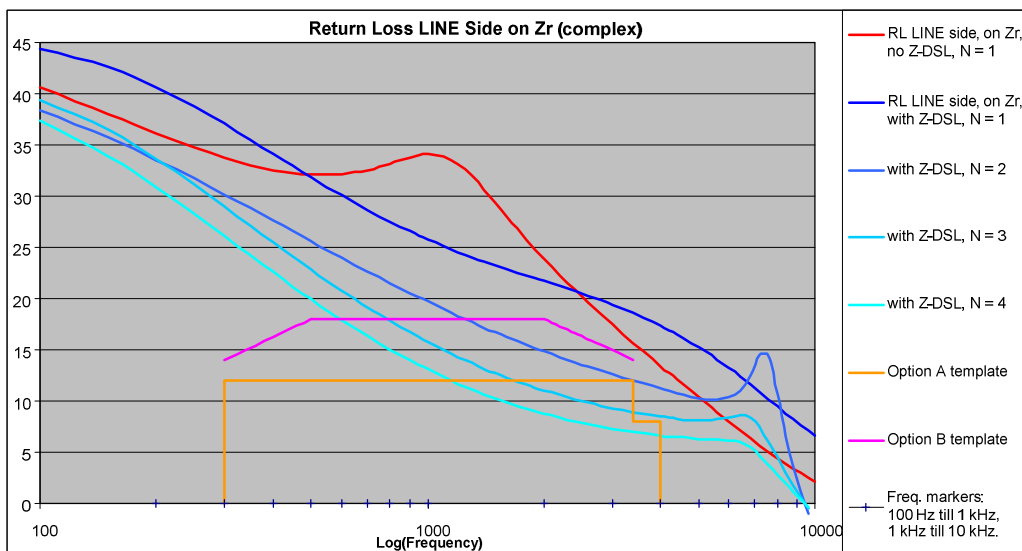


Figure C.2: Effect of 1 to 4 distributed filters on the Return Loss at the LINE port

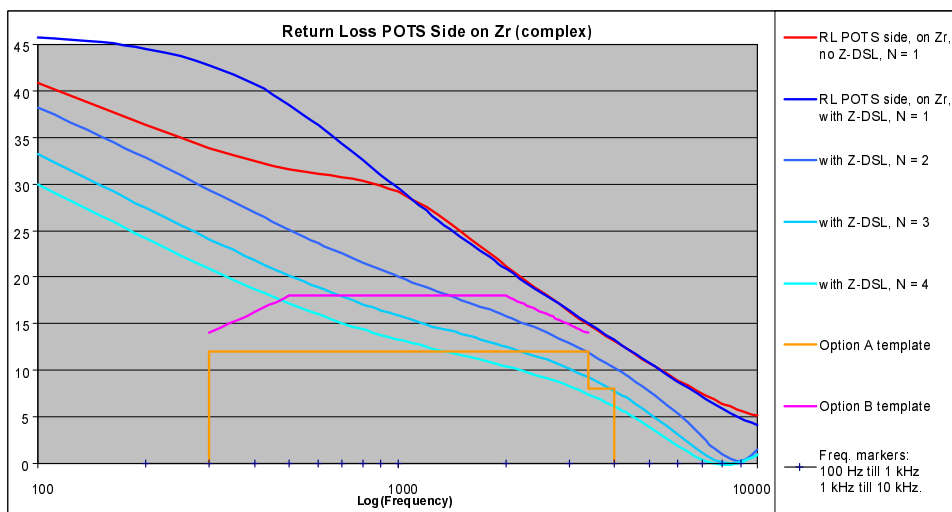


Figure C.3: Effect of 1 to 4 distributed filters on the Return Loss at the POTS port

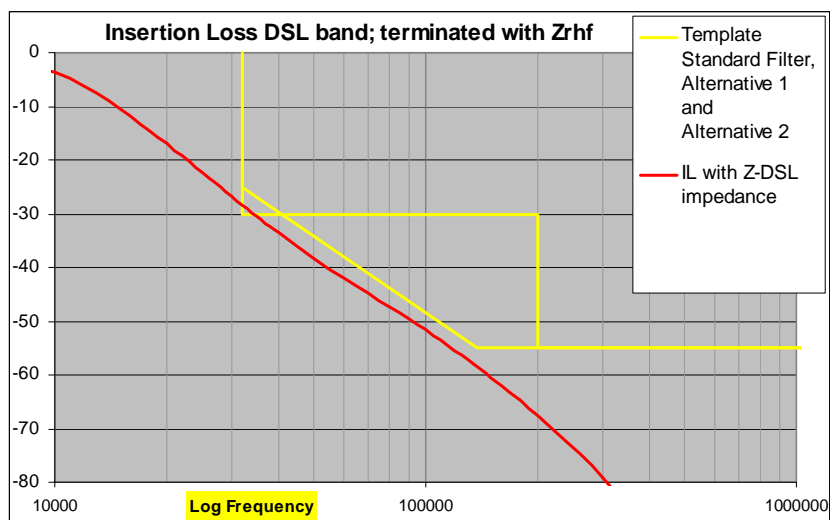


Figure C.4: IL of a single filter in the xDSL band

Note that the IL in the xDSL band will not be change significantly, when parallel devices are deployed, Therefore it is only measured or simulated for a single device.

C.2 Trade-off between properties in POTS band and xDSL band

In this clause we show the trade-offs between POTS band and xDSL band performance. The filters shown are Enhanced filters, first in option A and then in Option B. Note that these enhanced filters are rather complex devices. In fact this clause also shows that the requirements of this type of filters are feasible.

For each option A and B filter we show 4 elements:

- 1) the IL in the POTS band,
- 2) the RL at POTS port,
- 3) the RL at the LINE port,
- 4) the IL in the xDSL band.

The results are shown for a single filter when the xDSL is absent (a red line) and then in the presence of xDSL (i.e. with Z_{DSL} at the LINE port), for 1, 2, 3 and finally 4 parallel filters (in blue lines of different shade).

We note that the IL in the POTS band for the option A case is within the requirements for the Option A filters, when 4 are installed. For the Option B filters the IL is much better (i.e. less losses). The RL can be kept within the Option (A or B) for both types of filters. The RL at the LINE port stays OK, even for up to 4 parallel filters when Z_{DSL} is present.

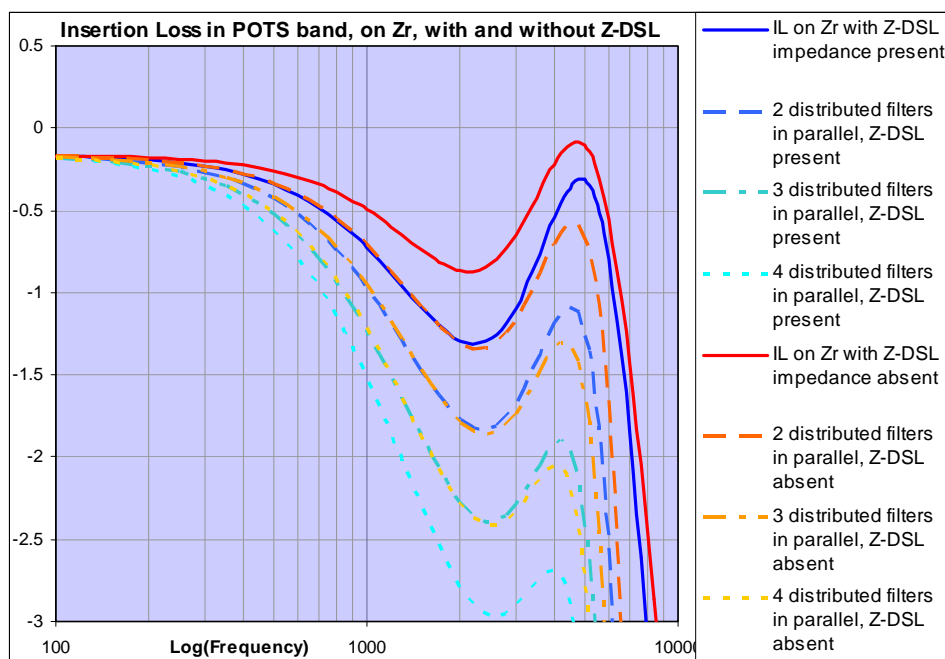


Figure C.5: Enhanced Option A Filter; Insertion Loss in the POTS band for 1 to 4 filters

Remark on this Option A design: the IL in the POTS band is just within the requirements (3 dB for 4 filters).

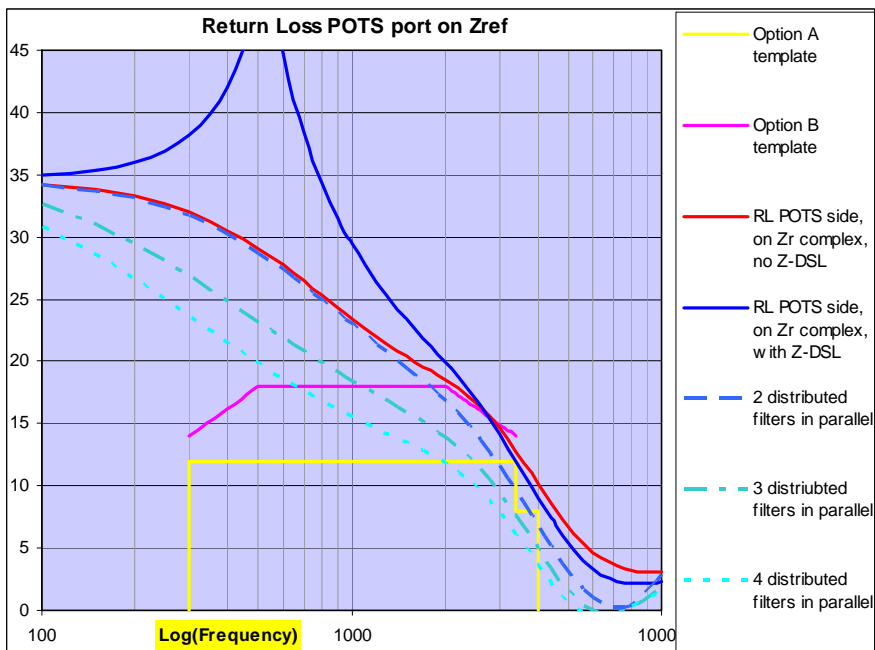


Figure C.6: Enhanced Option A Filter; Return Loss at the POTS port for 1 to 4 filters

Small remark on this Option A design: the RL at the POTS port drops below Option A for multiple devices, but this is not a requirement in the present document, because this is a sidetone enhancement and not an echo effect.

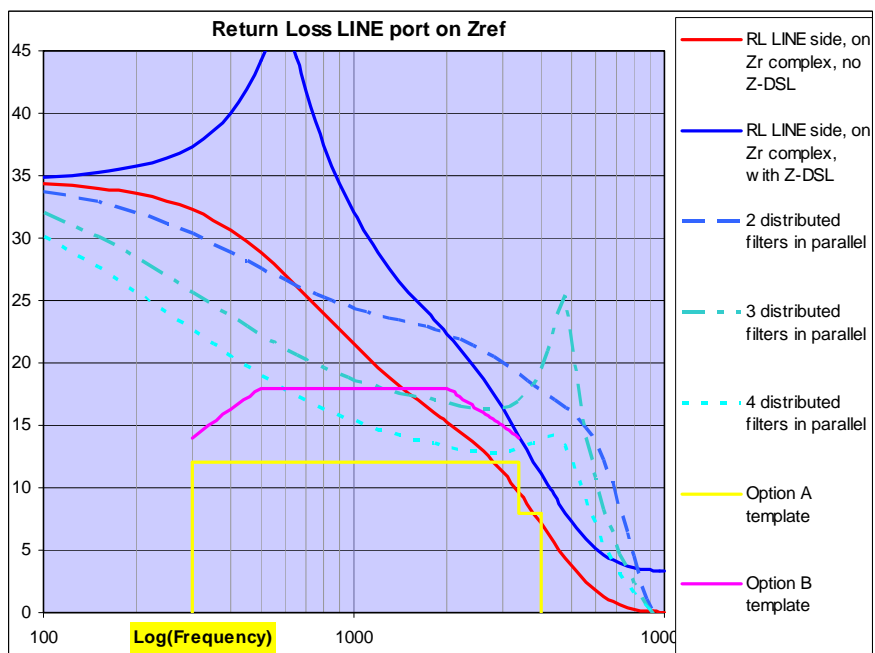


Figure C.7: Enhanced Option A Filter; Return Loss at the LINE port for 1 to 4 filters

Small remark on the Option A design: When Z_{DSL} is absent for a single filter, the RL is below Option A for a single device. However, detailed analysis shows that RL will be above Option A for 2 to 4 devices when Z_{DSL} is absent.

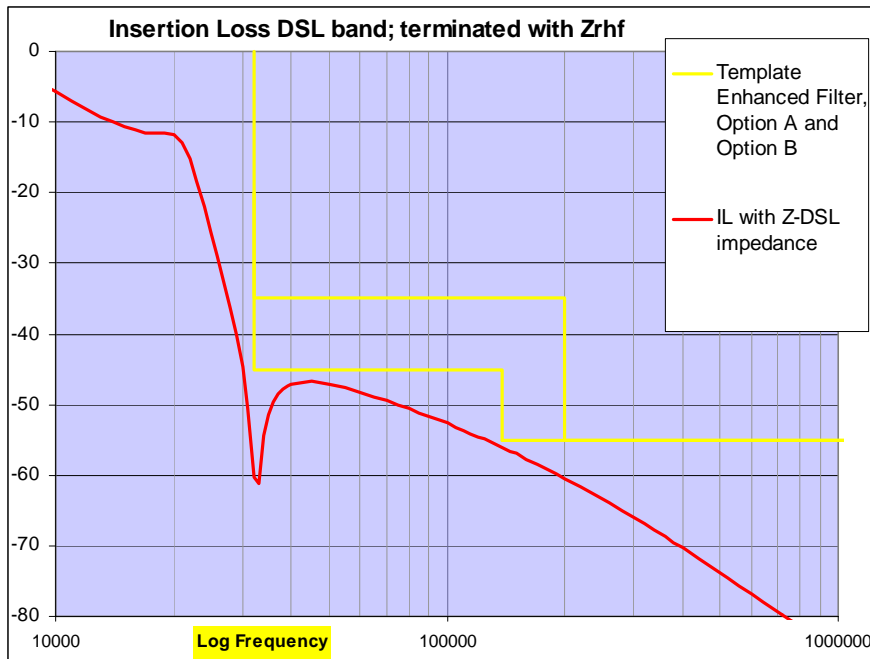


Figure C.8: Enhanced Option A Filter; Insertion Loss in the xDSL band

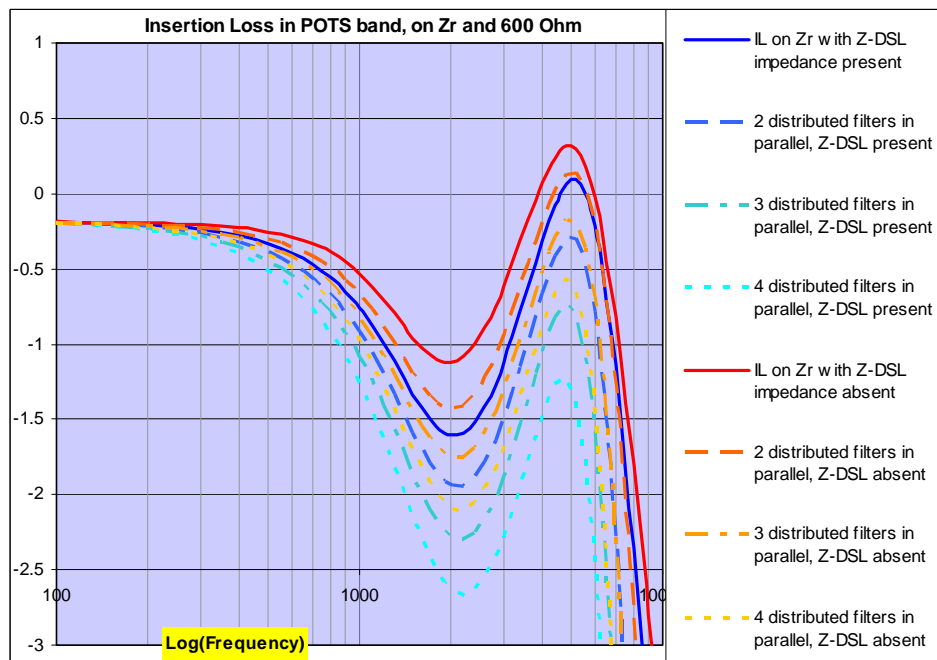


Figure C.9: Enhanced Option B Filter; Insertion Loss POTS band for 1 to 4 filters

We notice that compared to Figure C.5, the IL in the POTS band is better for Option B than for Option A.

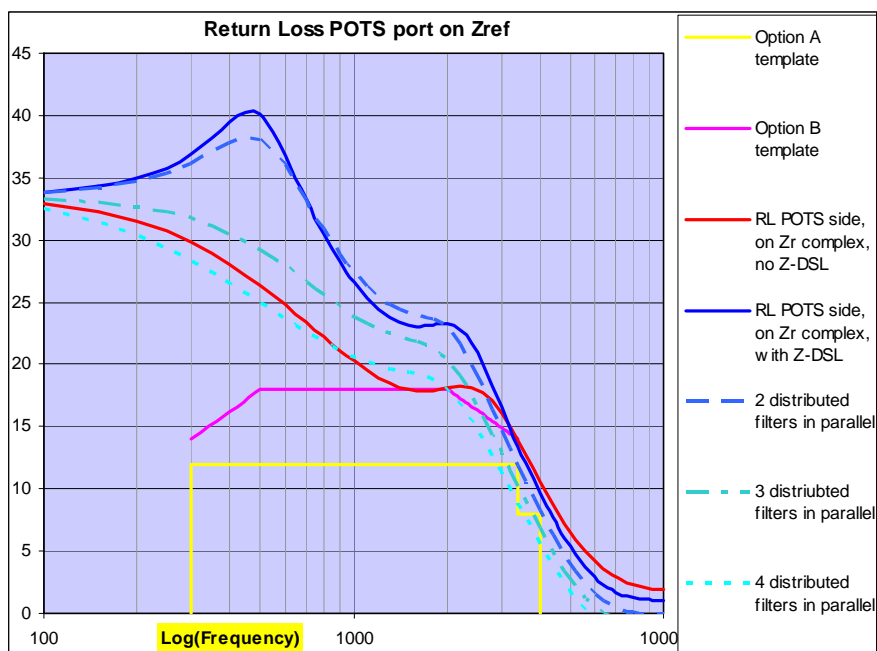


Figure C.10: Enhanced Option B Filter; Return Loss at the LINE port for 1 to 4 filters

Small remark on this Option B design: the RL at the POTS port drops below Option B for multiple devices, even cutting the Option A template, but this is not a requirement in the present document, because this is a sidetone enhancement and not an echo effect. The RL at the LINE port is superior and above the template with large margins.

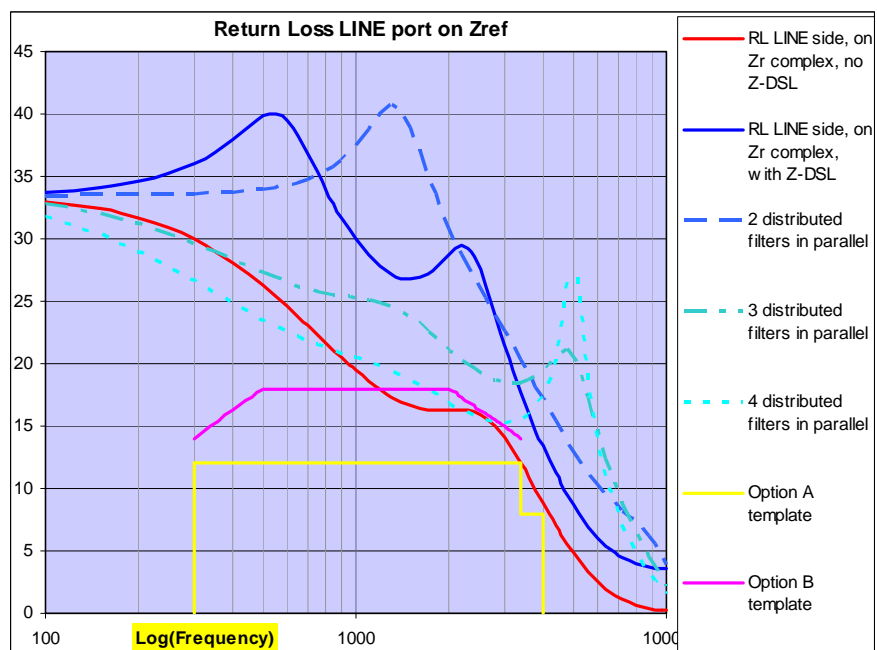


Figure C.11: Enhanced Option B Filter; Return Loss at the LINE port for 1 to 4 filters

Small remark on the Option B design: When Z_{DSL} is absent for a single filter, the RL is below Option A for a single device. However, detailed analysis shows that RL will be above Option A for 2 to 4 devices when Z_{DSL} is absent. Also the 4 parallel devices cut the main template of the RL, but are above the reduced templates of [Clause 6.6.3.3](#).

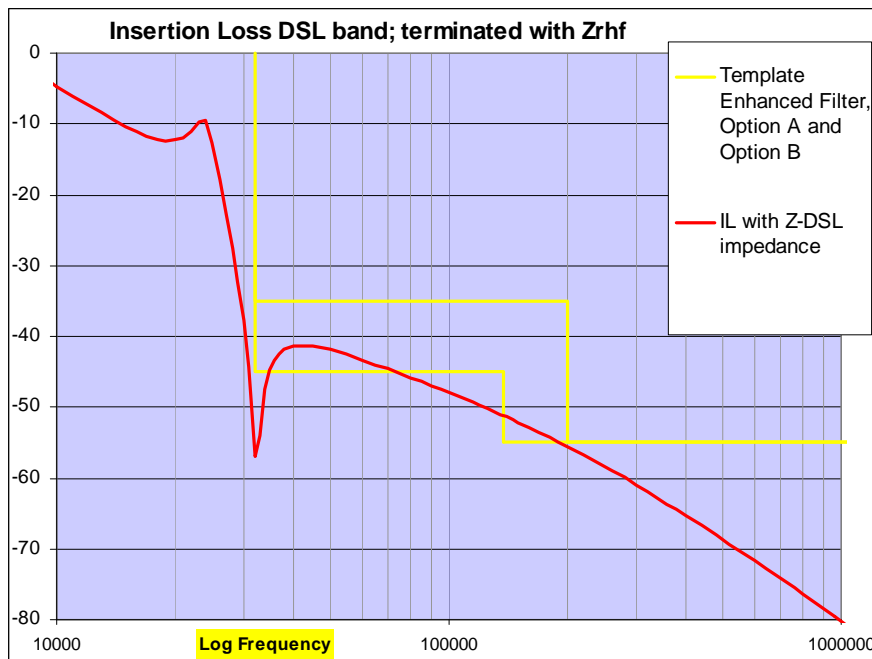


Figure C.12: Enhanced Option B Filter; IL in the xDSL band

We notice that compared to Figure C.8, the IL in the xDSL band is better for Option A than for Option B.

Conclusions are simple: By achieving RL Option B, i.e. better than Option A, the IL in the POTS band is also better for Option B than for Option A filter(s), while the IL in the xDSL band is less good for Option B than for Option A filters.

C.3 Strong IL in the xDSL band affects POTS quality

When the design of a distributed filter is optimized for single use, based on the earlier version of the filter document, then this can have severe issues on the parallel operation. This is already the case for the filter in [Clause C.1](#). This filter is designed for optimal Option B operation when only a single device is present. It is superior in terms of IL in the xDSL band, where it reaches an IL of 28 dB at 32 kHz and 58 dB at 138 kHz and 67 dB at 200 kHz, which was a strong result for a filter with an Option B RL according to the previous version of the present document. Unfortunately this filter with a strong IL in the xDSL band has severe issues in the POTS band, because RL and IL drop well below the templates for 3 and 4 parallel devices.

C.4 Effects of parallel filters differ at POTS and LINE port

The effect of the parallel distributed filters on RL and IL in the POTS band is different at the POTS port and the LINE port of the filters. Also the effect of removing the xDSL transceiver has different effects at both ports, as explained in the [Clause C.5](#).

The effect of adding extra parallel distributed filters will have different effects at POTS port and at LINE port.

- 1) Extra parallel filters will always worsen (increase) the IL in the POTS band. Note that IL is the same from POTS port to LINE port and reversed. This can be seen in Figures C.1, C.5 and C.9.
- 2) At the POTS port extra parallel filters will cause the RL to drop. This can be seen in Figures C.2, C.3 and C.10. Typically, a single filter will only marginally meet the RL requirement at the POTS port, for both Option A and B. This means that for multiple filters the RL at the POTS port will drop below the template. Luckily at the POTS port the RL causes only a sidetone enhancement and not an ECHO effect.

- 3) At the LINE port the RL can be kept sufficiently high and above the templates, even when parallel filters are installed. Sometimes for filters with relatively limited input capacitance in the POTS band, the RL even improves slightly, when a few filters are in parallel. However ultimately, when a sufficiently large number of filters are installed, the RL will drop below the templates (Option A or B). This can be seen in Figures C.3, C.7 and C.11.

C.5 The effects of absence of the xDSL impedance Z_{DSL}

When a set of distributed filters are installed, they are used normally in the presence of the xDSL transceiver, of which the input capacitance is the dominant factor in the POTS band. The RL is supposed to be OK at both LINE and POTS port. When the xDSL transceiver is removed, the input capacitance of the xDSL transceiver is absent, which typically caused the IL of the filters to improve. However, the RL changes differently at the POTS and the LINE port.

The IL effect is shown in the Figures C.1, C.5 and C.9, where the red line is above the blue line for a single filter. Also for 2 to 4 filters, the IL will always be better in the absence of Z_{DSL} than in the presence of Z_{DSL} . This is shown in Figures C.5 and C.9, which contains all cases of parallel filters in the absence of Z_{DSL} . Similar results will be seen when adding the extra cases in the absence of Z_{DSL} to the Figure C.1.

However, for multiple filters the RL changes differently at the POTS and the LINE port when Z_{DSL} is removed.

- At the LINE port the removal of Z_{DSL} (i.e. it is dominating input capacitance) causes the RL to drop. This can be seen in the red lines in the Figures C.3, C.7 and C.11. Luckily, each additional filter will not always worsen this situation, because adding parallel distributed filters is adding some capacity in parallel with the filter, which is similar to bringing the Z_{DSL} back to the installation, which restores the better situation with Z_{DSL} .
- At the POTS port the removal of Z_{DSL} (i.e. it is dominating input capacitance) causes the RL not to drop, and sometimes even to improve. This can be seen in the red lines in the Figures C.2, C.6 and C.10. However, after some improvement when adding a first extra filter, the RL will then start to drop for each additional filter.

Annex D (informative): Intrinsic IL and RL caused by the Z_{DSL} in the POTS band

The IL in the POTS band is measured according to a diagram (see Figures 11 and 12) in which Z_{DSL} is not present in the reference case. The fact that Z_{DSL} is only present when the IL of the central splitter or distributed filter is measured causes additional signal losses introduced by the Z_{DSL} . This extra loss due to the Z_{DSL} limits the IL loss caused by the low pass, because the combined IL of both low pass and Z_{DSL} should be within the allowed boundaries.

For the IL in the DSL band the xDSL impedance Z_{DSL} is not present in the reference measurement. This means that the IL is enhanced favourably by some extra loss caused by the Z_{DSL} in the measurement with the DUT present.

A similar reasoning can be done for the RL. RL is measured for the combination of the splitter low pass or distributed filter in the presence and absence of the xDSL transceiver. However, it is clear that the Z_{DSL} on its own causes a degradation of the RL, which limits the amount of additional RL the central splitter or distributed filter can cause.

Examples of the intrinsic IL and RL degradation caused by Z_{DSL} are given in the Annex D of TS 101 952-1 [11].

The effect of Z_{DSL} on IL is also shown in the Figures C.1, C.5 and C.9 in [Annex C](#).

Annex E (informative): IL Measurement from LINE to xDSL inside Z_{DSL}

For the IL from LINE to xDSL port in theory the signal could be measured or generated inside the Z_{DSL} on the R_{DSL} termination impedance. However, this does not change the measurement result. The related alternative test set-ups are partially documented in this informative annex.

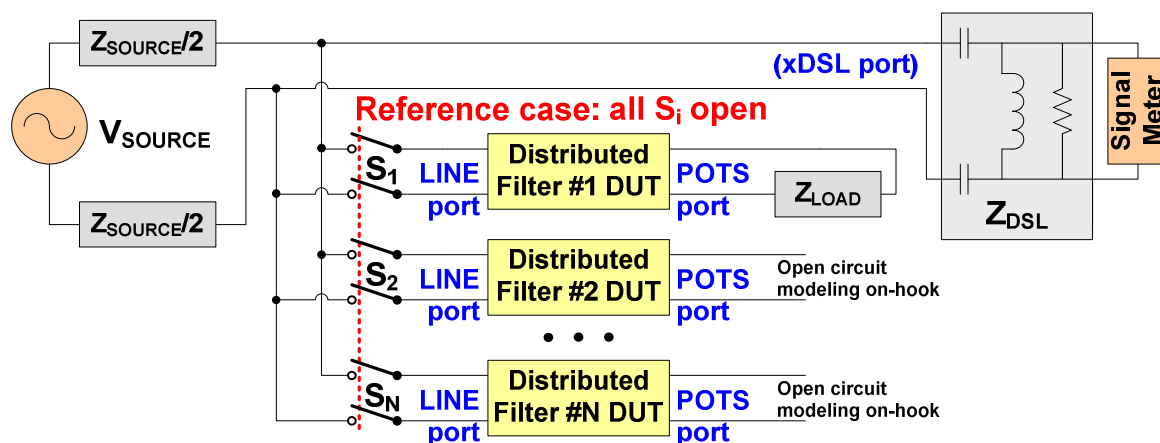


Figure E.1: Test set-up for Insertion Loss from POTS port to xDSL port, measured at R_{DSL}

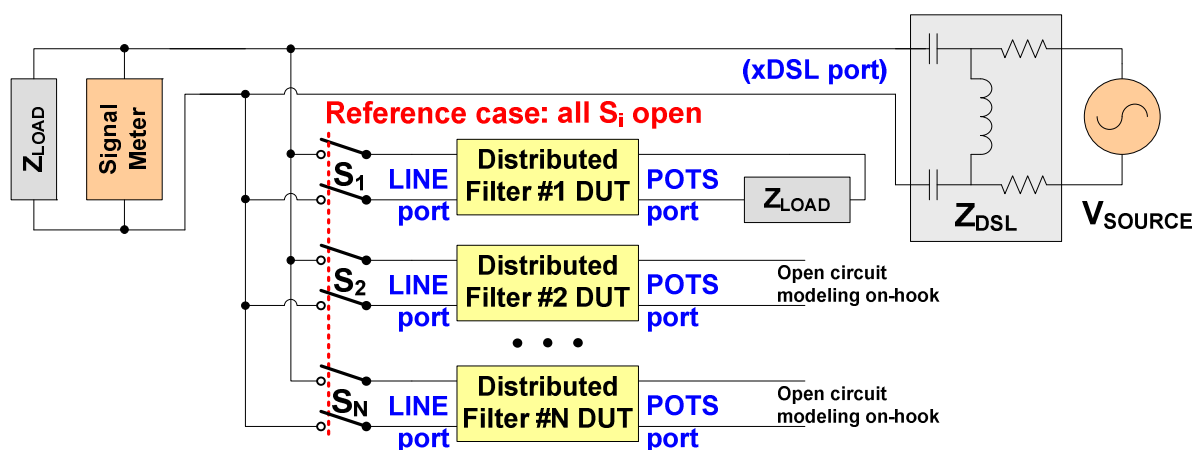


Figure E.2: Test set-up for Insertion Loss from xDSL port to POTS port, injected at R_{DSL}

For additional Figures, please refer to Annex E of TS 101 952-1 [11]. Annex E of TS 101 952-1 [11] contains more the relevant information on this subject.

The only extra elements to be added in this Annex E of [11] are the extra on-hook filters in parallel with the main filter DUT. As discussed in note 4 in [Clause 5.4](#), the filters in on-hook have to be left open at their POTS port.

Annex F (informative): Return Loss measurements: practical diagrams

To measure the input impedance of a distributed filter terminated with a load impedance and to calculate the RL according to the formula of [Clause 5.4.6](#), the following practical diagram in Figure F.1 shows a bridge scheme with which the RL at the LINE port can be calculated by measuring voltages instead. It is possible to balance this scheme, but it is not absolutely necessary. Z_{SOURCE} is Z_{Ref} in the formula of Clause 5.4.5. Z_{Aux} is an auxiliary impedance.

For determining the RL of a distributed filter according to the formula defined in [Clause 5.4.6](#), Z_{SOURCE} in the Figures F.1 and F.2 should be identical to Z_{LOAD} . Z_{LOAD} is the impedance at the POTS port of the filter DUT #1 in Figure F.1 and at the LINE port in Figure F.2.

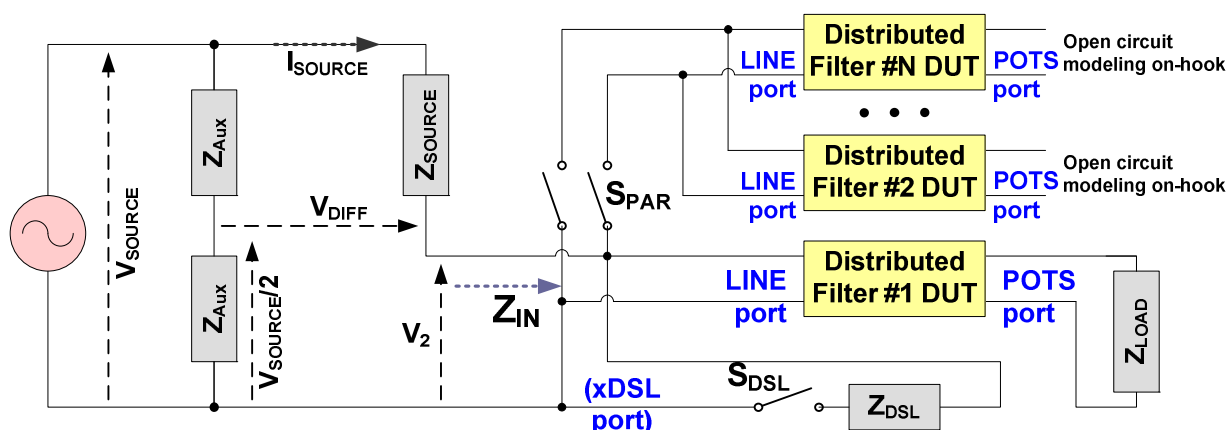


Figure F.1: Practical test set-up for Return Loss at the LINE port

A similar practical test set-up for Return Loss at the POTS port can be derived as shown in Figure F.2.

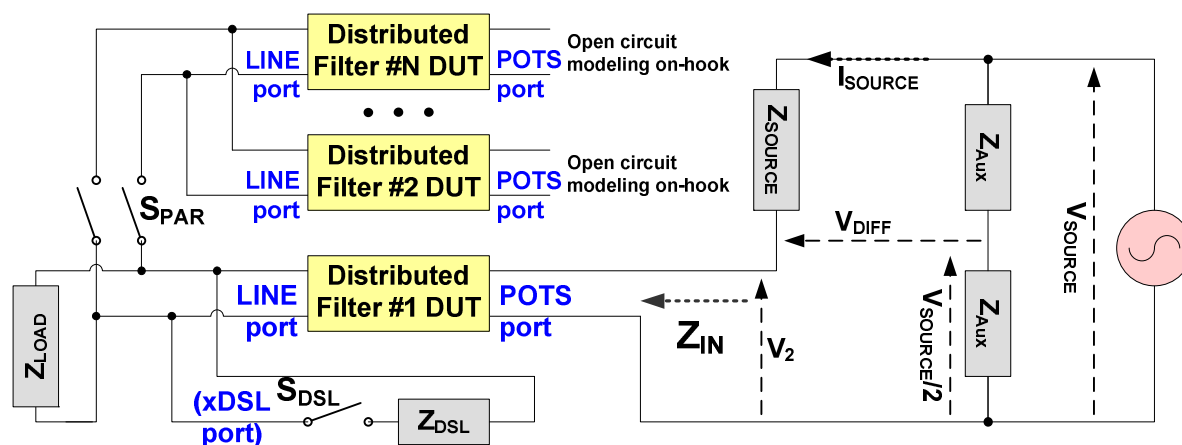


Figure F.2: Practical test set-up for Return Loss at the POTS port

The applicable formula for the RL is:
$$RL = 20 \times \log \left(\frac{|V_{SOURCE}/2|}{|V_{DIFF}|} \right)$$

This can be derived as follows:

$$\begin{aligned}
 RL &= 20 \times \log \left(\frac{|Z_{SOURCE} + Z_{IN}|}{|Z_{SOURCE} - Z_{IN}|} \right) = 20 \times \log \left(\frac{|Z_{SOURCE} + Z_{IN}|}{|Z_{SOURCE} + Z_{IN} - 2 \times Z_{IN}|} \right) = \\
 &20 \times \log \left(\frac{|V_{SOURCE} / I_{SOURCE}|}{|V_{SOURCE} / I_{SOURCE} - 2 \times Z_{IN}|} \right) = 20 \times \log \left(\frac{|V_{SOURCE}|}{|V_{SOURCE} - 2 \times V_2|} \right) = 20 \times \log \left(\frac{|V_{SOURCE} / 2|}{|V_{DIFF}|} \right)
 \end{aligned}$$

Annex G (informative): Insertion Loss measured with feeding and loading bridges

It is necessary to combine the measurements described in [Clauses 5.4, 5.5, 5.6](#) and [5.7](#) with the DC conditions of [Clause 5.1](#). This requires the combination of the circuits of the Figures 11 to 18 with the feeding and loading bridges of [Clause 5.1.3](#).

However, please refer to TS 101 952-1 [11]. Annex G of TS 101 952-1 [11] contains relevant information on this subject.

The only extra elements to be added in the Annex G of TS 101 952-1 [11] are the extra on-hook filters in parallel with the main filter DUT. Therefore, we show two figures in which we add the extra filters with the on-hook filters.

The Figure G.1 shows the IL from LINE port to POTS port, when the (N-1) additional filters in parallel have an open circuit at their POTS port.

The Figure G.2 shows the same IL case, but the complicated and optional version when each additional filter is connected to a finite on-hook impedance Z_{OnHo} , as explained in [Annex L](#).

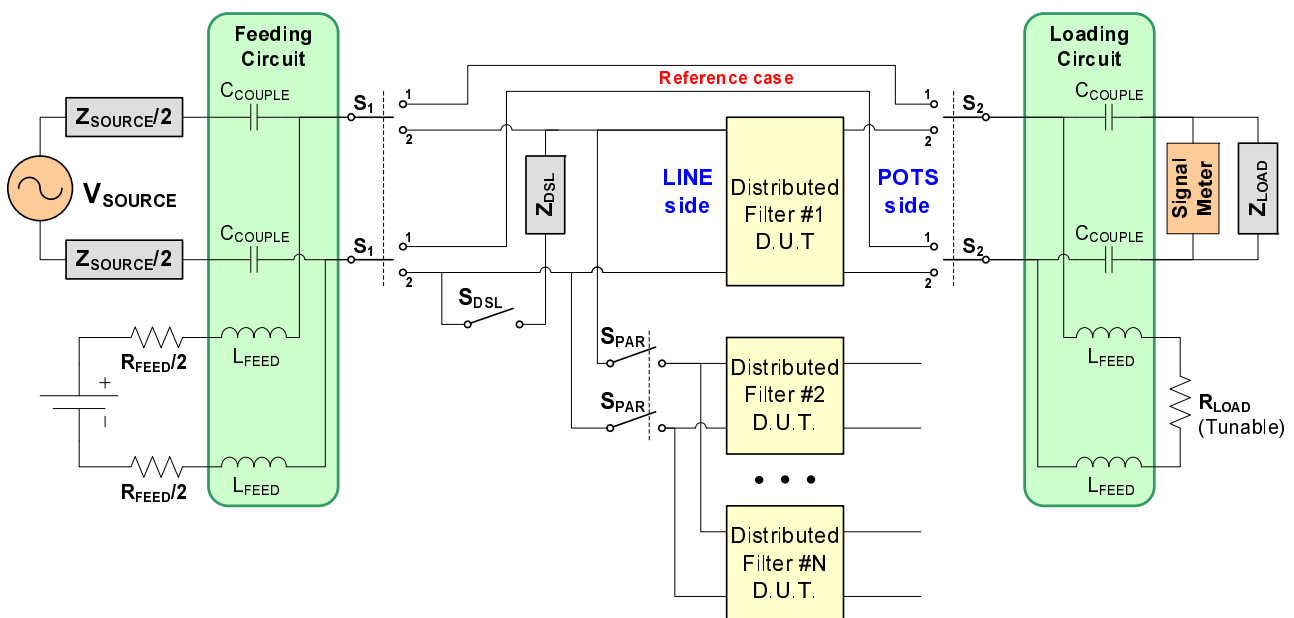


Figure G.1: Test set-up using feeding bridges for IL of distributed filters from LINE port to POTS port

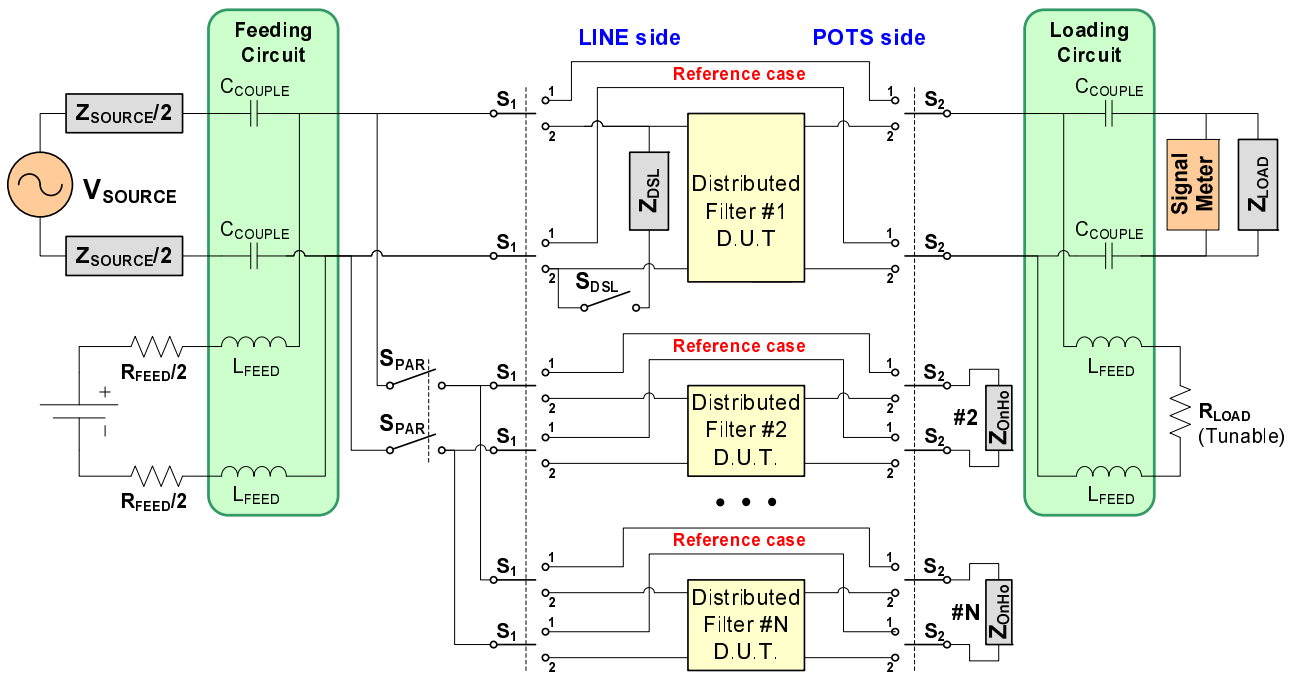


Figure G.2: Same example of the use of feeding bridges but with finite on-hook impedance

Annex H (informative): Dynamic tests of distributed filters in the presence of xDSL transceivers

H.1 General Description of TR-127 of the Broadband Forum

For the general description of TR-127 [i.15] (published as Technical Report by the broadband forum) please refer to TS 101 952-1 [11]. In Annex H of TS 101 952-1 [11] the case of POTS related dynamic tests are explained in detail.

H.2 Distributed filter tests in TR-127.

For the distributed filters additional tests are described in TR-127 [i.15]. TR-127 [i.15] includes the following:

- 1) Static tests with one filter device in off-hook and other parallel filters in on-hook, with a ringer model attached to the POTS port of each on-hook filter.
 - This test checks how the presence of additional filters might reduce the achievable bitrate or the performance in general, when a phone is off-hook.
- 2) Static tests with one filter under permanent ringing are extended to multiple parallel devices, with a ringer model attached to the POTS port of each filter.
 - This test checks how the presence of additional filters might reduce the achievable bitrate due to ringing.
- 3) Dynamic tests with one DUT changing on-hook to off-hook with other parallel filters in on-hook.
 - This checks if the presence of additional devices in on-hook might affect the performance of the DUT.
- 4) Dynamic tests with one filter under cadenced ringing, extended to multiple parallel devices.
 - This test checks how the presence of additional filters might reduce the achievable bitrate or the performance in general.
- 5) Dynamic tests with one DUT in ring-trip under cadenced ringing with other parallel filters in on-hook.
 - This checks if the presence of additional devices in on-hook might affect the performance of the DUT.

Annex I (informative): Optimal transmission of POTS and xDSL signals and their separation

This annex is intended as a general tutorial describing how POTS and xDSL should be affected minimally by central splitters or distributed filters and how the POTS and xDSL should be separated (or prevented from interworking) by the splitters or filters.

Please refer to part one the present multipart document, TS 101 952-1 [11]. Annex I of part 1 contains a general tutorial describing precisely these issues.

Annex J (informative): More on feeding and loading bridges

Please refer to Annex J of part one the present multipart document, TS 101 952-1 [11]. Annex J of part 1 contains the relevant information on this subject.

Annex K (informative): Additional requirements for Active Filters (F.F.S.)

The present document is limited to passive and static dynamic filters as stated in the [Introduction](#).

For active (and potentially also dynamic) filters additional tests are required and they are F.F.S. However, the following dedicated tests were already identified:

- DC resistance.
- Bidirectional IL tests might be needed.
- Noise tests ([Clauses 5.6](#) and [6.10](#)).
- Distortion ([Clause 6.11](#)).
- Transitional tests ([Clause 6.13](#)).

NOTE: As stated in the [Introduction](#), it is planned that this work on active and dynamic is done in part 4 [i.14] of the series of splitter documents.

K.1 DC series resistance

For active filters the resistive drop (see [Clause 6.2.2](#)) should be altered to a voltage drop, which would be required for active elements, used to improve other static properties, which are difficult to realise with passive filters.

K.2 Bidirectional IL tests

The IL tests of passive distributed filters can be limited to a single direction, as stated in note 1 of [Clause 5.4.1](#). However, for active distributed filters this no longer applies. Therefore, all IL measurements for active distributed filters should be conducted in both directions. This applies to multiple clauses under clause 6. The details are F.F.S.

K.3 Noise measurements methods for active filters

Noise requirements were unnecessary for passive distributed filters. This does not hold for active distributed filters. [Clauses 5.6.1](#) and [5.6.2](#) should be provided and requirements should be stated for [Clauses 6.10.1](#) and [6.10.2](#).

K.3.1 Psophometric noise in the POTS Band

The psophometric noise power (see [Clauses 5.6.1](#) and [6.10.1](#)), as defined in ITU-T Recommendation O.41 [4], is measured at the LINE port and the POTS port of a distributed filter. The psophometric level should be referenced to Z_R . LINE port and POTS port should be terminated with Z_R . The xDSL port should be terminated with the Z_{DSL} load as defined in [Clause 5.2.1](#).

K.3.2 Noise in the xDSL Band

This clause relates to [Clauses 5.6.2](#) and [6.10.2](#). It is still F.F.S., however, the noise in the xDSL band in active/dynamic distributed filters could quite likely be measured indirectly with the TR-127 methodology, developed by the Broadband Forum. The methodology of the TR-127 [i.15] test is introduced and described in the informative [Annex H](#). The TR-127 [i.15] methodology allows detecting distortion and noises caused by a distributed filter device. This is done by measuring the xDSL rates in a few steps. First it is done without splitters or filters, then with baseline devices and finally with a baseline device and a splitter or filter as DUT. If the noise would be too high, a drop of bitrate and/or of margin will be observed, which can be attributed to the DUT.

K.4 On-hook loss requirements for dynamic or active filters

The IL of a single dynamic or active filter, which is expected to be standard or enhanced quality, could be assessed according to Table K.1.

Table K.1: On-hook loss, minimum values (values to be confirmed)

Frequency range	Minimum value
32 kHz to 350 kHz	18 dB
350 kHz to f_H	55 dB

K.5 Noise requirements for active filters

The noise requirements of [Clause K.3.1](#) should be met only for the off-hook condition of the TE. The noise requirements of [Clause K.3.2](#) should be met for both the on-hook and off-hook condition. The DC feeding conditions are given in [Clause 5.1.2](#).

K.5.1 POTS band audible noise level

The psophometric noise power NPB (see [Clause 6.10.1](#)) should be measured according to [Clause K.3.1](#) at the LINE port and the POTS port of a filter. The values are F.F.S.

K.5.2 xDSL band noise level

For active filters the xDSL band noise (see [Clause 6.10.2](#)) is tested, by observing an adequate xDSL operation with the methodology of the TR-127 of the Broadband Forum, as introduced in informative [Annex H](#).

The requirements can be stated as an allowed margin and/or bitrate reduction. The values are F.F.S.

K.6 Distortion

This clause relates to [Clause 6.11](#) and is F.F.S.

K.7 Transitional tests

This clause relates to [Clause 6.13](#) and is F.F.S. The dynamic and active filters might alter their topology or impedance, which might affect the xDSL transmission due to induced errors. Likely the TR-127 [i.15] methodology, developed by the Broadband Forum will be used. The methodology of the TR-127 [i.15] test is introduced and described in the informative [Annex H](#).

Annex L (informative): Amending the IL measurements for finite Z_{OnHo}

In [Clauses 5.4.2](#) and [5.4.3](#) the IL is measured with 1 to N distributed filters in the test set-up. To simplify these tests the N-1 filters in the on-hook state are kept open at their POTS port. This was decided because too many cases of measurements were encountered, in which the reference cases were done incorrectly, when the on-hook impedance was not infinite. However, one could insist to measure the IL when a Z_{OnHo} that is **not** infinity is attached to the on-hook filters. However, then the diagrams in clause 5 are not correct, and they need to be amended as shown (for information) in this clause.

The simplified IL measurement between LINE port and POTS port is shown in the Figures 11 and 12, which are reduplicated below in Figures L.1 and L.2. The additional filters 2 to N are left open at their POTS port.

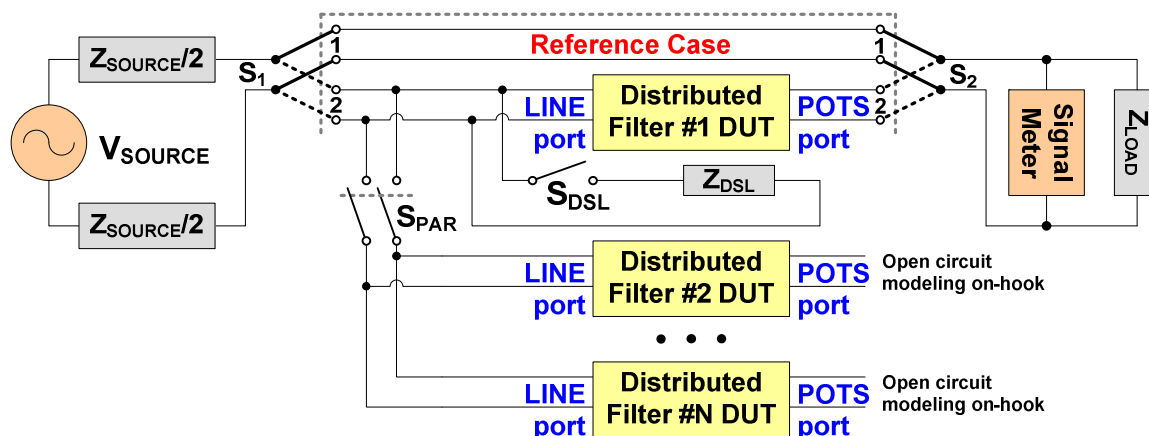


Figure L.1: Test set up for IL testing from LINE port to POTS port (\equiv Figure 11)

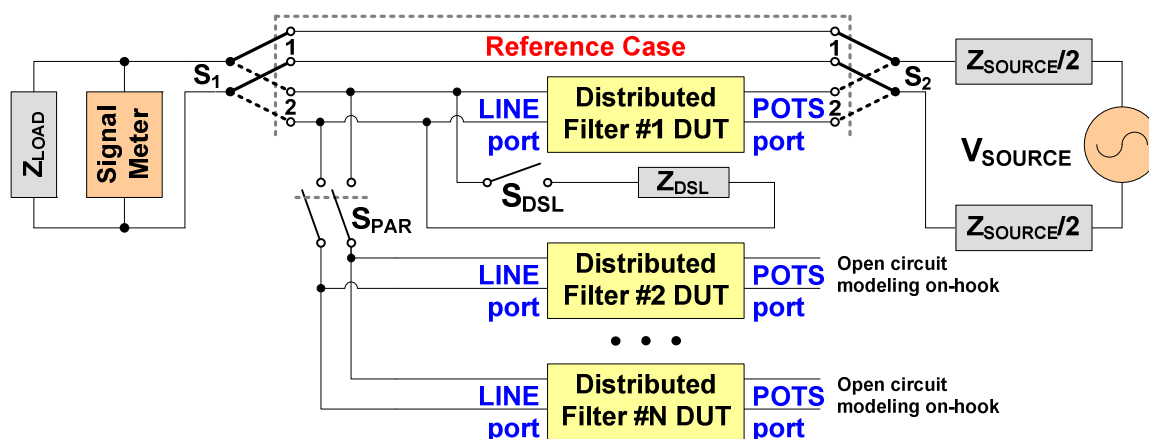


Figure L.2: Test set up for IL testing from POTS port to LINE port (\equiv Figure 12)

If a finite Z_{OnHo} is attached to the POTS port of the filters 2 to N, then it is important that extra switches are added in the reference case. If a measurement is done with a finite Z_{OnHo} , the figure As show, the N-1 parallel filters are terminated with an open circuit at their POTS port. L.1 and Figure L.2 (as in clause 5) are not correct.

If the tests are done with Z_{OnHo} attached to the filter DUTs 2 to N (i.e. in the on-hook state), the reference situation should be corrected to contain the N-1 Z_{OnHo} impedances. The IL figures should contain a set of switches, which need to be put in the reference case first and later should connect the main DUT and the extra N-1 DUTs in on-hook. This requires that the switches S1 and S2 should be replicated for each distributed filter, as shown in the Figures L.3 and L.4. In this way the Z_{OnHo} impedances attached to the N-1 distributed filters are correctly present in the reference measurement.

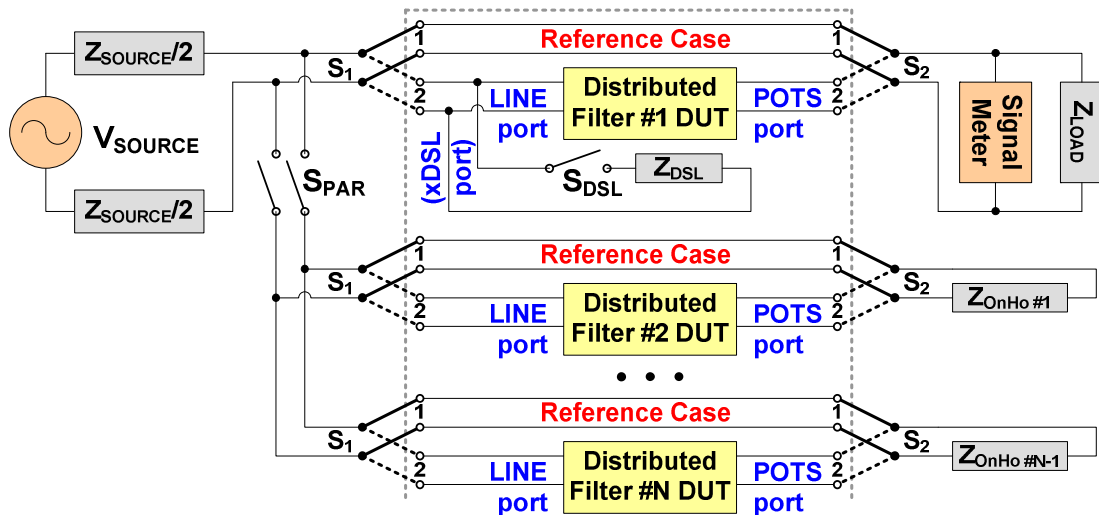


Figure L.3: Test set up for IL testing from LINE port to POTS port, when Z_{OnHo} is used

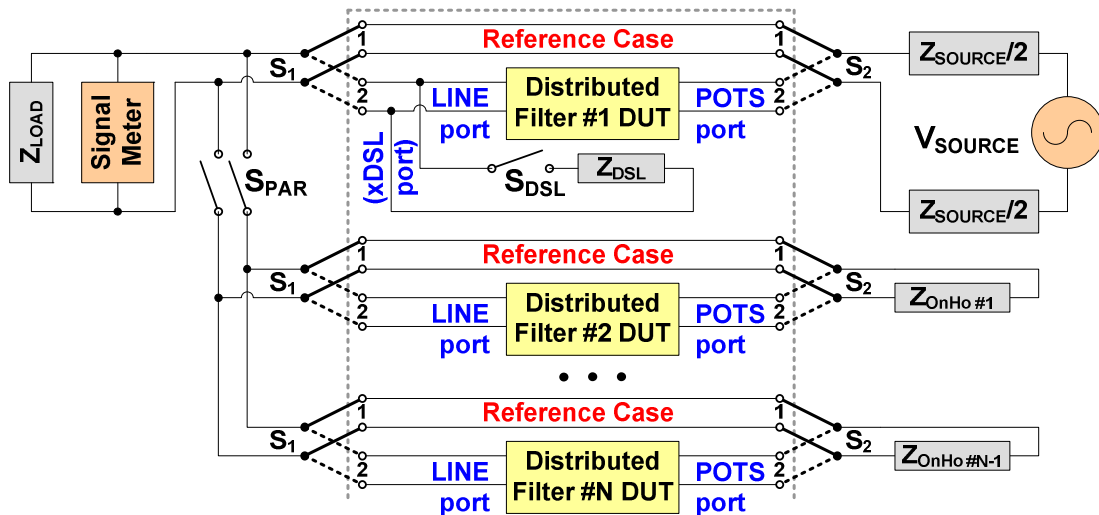


Figure L.4: Test set up for IL testing from POTS port to LINE port, when Z_{OnHo} is used

The test set-up from POTS port to LINE port can be altered with fewer switches to insert the N devices under test, as shown in the Figures L.5 and L.6. However, this requires replicating each individual Z_{OnHo} impedance twice as shown.

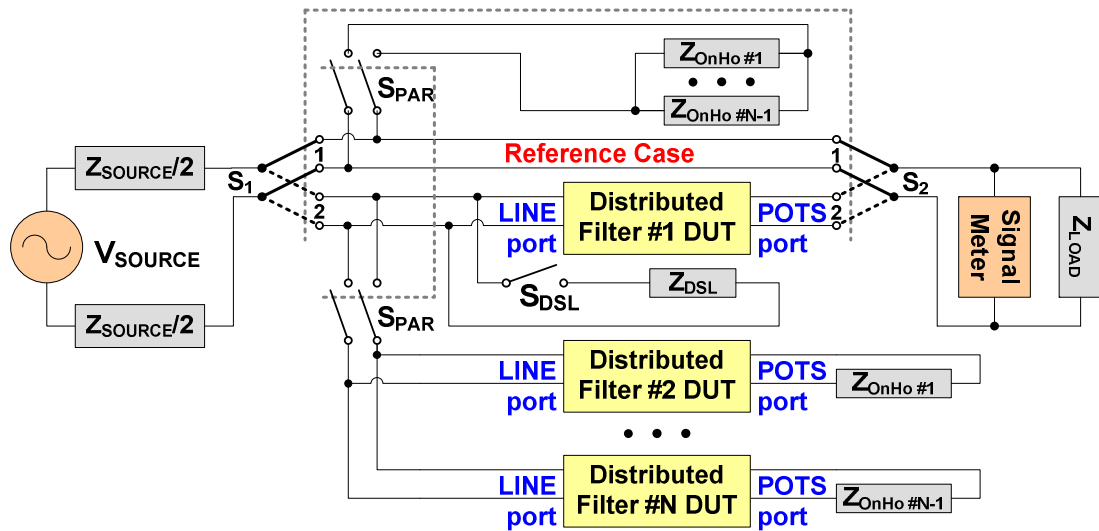


Figure L.5: Alternative test setup for IL testing from LINE port to POTS port, when Z_{OnHo} is used

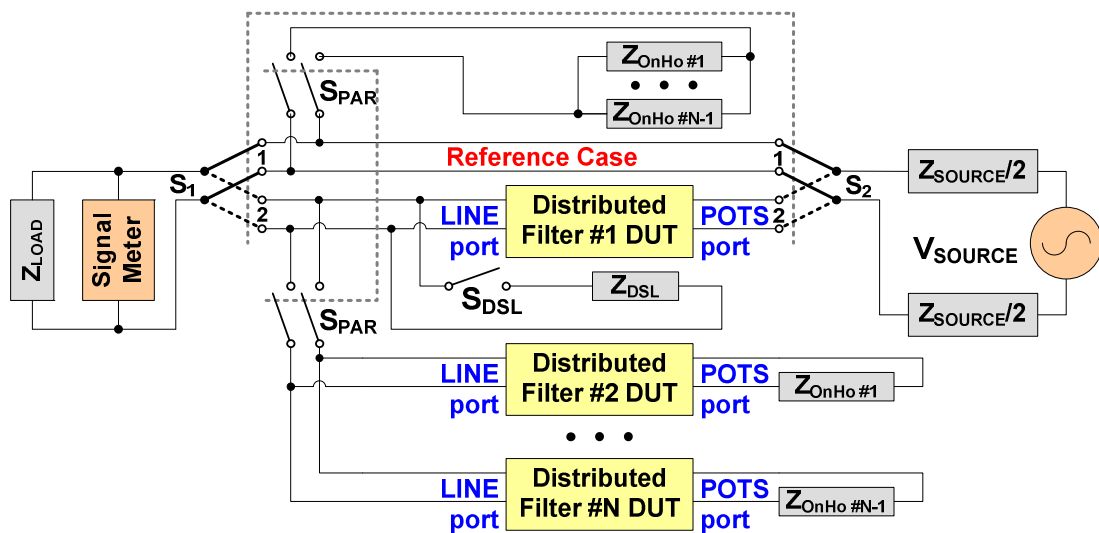


Figure L.6: Alternative test setup for IL testing from POTS port to LINE port, when Z_{OnHo} is used

Annex M (informative): Bibliography

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".

ETSI ES 201 187: "2-wire analogue voice band interfaces; Loop Disconnect (LD) dialling specific requirements".

ETSI TS 102 080: "Transmission and Multiplexing (TM); Integrated Services Digital Network (ISDN) basic rate access; Digital transmission system on metallic local lines".

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".

ETSI EG 201 188: "Public Switched Telephone Network (PSTN); Network Termination Point (NTP) analogue interface; Specification of physical and electrical characteristics at a 2-wire analogue presented NTP for short to medium length loop applications".

ETSI ES 202 971: "Access and Terminals (AT); Public Switched Telephone Network (PSTN); Harmonized specification of physical and electrical characteristics of a 2-wire analogue interface for short line interface".

ETSI TS 101 270-1 (V1.2.1): "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very high speed Digital Subscriber Line (VDSL); Part 1: Functional requirements".

ITU-T Recommendation G.117: "Transmission aspects of unbalance about earth".

ITU-T Recommendation G.994.1: "Handshake procedures for digital subscriber line (DSL) transceivers".

ITU-T Recommendation G.995.1: "Overview of digital subscriber line (DSL) Recommendations".

ITU-T Recommendation G.996.1: "Test procedures for digital subscriber line (DSL) transceivers".

ITU-T Recommendation G.997.1: "Physical layer management for digital subscriber line (DSL) transceivers".

NOTE: ITU-T documents are available at: <http://www.itu.int/ITU-T/publications/recs.html>.

History

NOTE: Annex B explains how two earlier versions were published under a different numbering scheme.

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