# ETSI TS 101 952-1 V1.1.1 (2009-06)

*Technical Specification*

**Access network xDSL splitters
for European deployment;
Part 1: Generic specification of xDSL
over POTS splitters**

Reference

RTS/ATTM-06021

Keywords

ADSL, POTS, splitter, VDSL

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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 1 of a multi-part deliverable covering Access network xDSL splitters for European deployment, 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 distributed filters for xDSL over POTS";

Part 4: "Additional specifications for dynamic distributed filters for xDSL over POTS".

NOTE 1: 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 may be found in TR 101 953-1-1 [i.3], TR 101 953-1-2 [i.4], TR 101 953-2-1 [i.5] and TR 101 953-2-2 [i.6]. These documents are linked to the previous versions of the splitter specifications. [i.3], [i.4], [i.5] and [i.6] 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 older TR 101 953 series of documents, the present document prevails.

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

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 on and limitations of the present document

The present document covers all xDSL system variants, such as ADSL, ADSL2, ADSL2plus, VDSL1 and VDSL2. It is applicable at the Local Exchange (LE) (i.e. network) side of the line at the LE or at the cabinet and at the Terminal Equipment (TE) (i.e. user) side of the line. A number of limitations and remarks should be listed:

1) The use of the present documents is extended to splitters at the cabinet. Indeed, the previous versions of the present document clearly stated that they did not apply to splitters at the cabinet. However as explained in the informative annex C, this restriction was lifted.

2) The present document does not contain the requirements for splitters, which can handle both POTS and ISDN. These so-called xDSL over "ISDN or POTS" universal splitters are specified in part 2.

3) Splitters at the customer premises with a distributed topology, called distributed filters, are not within the scope of the present document. They are described in part 3 (and potentially part 4).

4) The present document covering xDSL over POTS splitters was gained from the experience with passive and static xDSL splitters, the original state of the art for this application. Furthermore, the experience was gained with identical requirements at either side of the line. Therefore, the requirements in the present document are primarily intended for passive and static filters, with identical requirements for the LE side and the TE side of the line. However, in the note under table A.3 an optional diversification between splitters requirements at the two sides of the line is described. For the TE side splitters an **optional** variant could be allowed with better downstream protection, with less IL in the upstream band and more IL in the downstream band. Similar differentiation between LE and TE is possible for the balance requirements, see the note under table A.10.

5) The present document covering xDSL over POTS splitters is limited to passive and static splitters. 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. The full specification of requirements for active/dynamic splitter is F.F.S. An introduction to this is in the informative annex K.

6) For certain static properties in the present document it is possible to relax the requirements and prove in dynamic tests that the splitter performs sufficiently well. These dynamic tests are compiled in WT-127, by the Broadband Forum. The use of the WT-127 methodology for this purpose is outside the scope of this version of the document, but could prove useful to introduce splitters with reduced complexity, or active and/or dynamic splitters. The WT-127 methodology is not fully finalized. It is described in annex H. Finalizing splitter tests in the present document based on WT-127 is F.F.S.

7) To test distortion, noise and other requirements in the present document the WT-127 methodology is sometime a superior methodology, or even the only feasible method at an acceptable complexity. Indeed, WT-127 will prove that a splitter works correctly in a worst case xDSL test environment. With such tests, based on actual xDSL transceiver results, one can avoid requirements are either inadequate or potentially unnecessarily strong. Defining splitter tests based on WT-127 in the present document is F.F.S.

# 1 Scope

The present document specifies requirements and test methods for the low pass and high pass part of xDSL over POTS splitters. These splitters are intended to be installed at the LE (i.e. network) side of the local loop, either at the local exchange or at a remote cabinet, and at the TE (i.e. user) side near the NTP. When used at the remote cabinet, the POTS signals can be injected locally at the cabinet, or at the central office. In the case of splitters at the TE side, the present document specifies the central splitter that is intended for use at the demarcation point of the customer premises.

The majority of requirements in the present document are generic and applicable to all xDSL over POTS central splitters. In the case where any requirements are applicable to only one particular flavour of xDSL, this is clearly indicated in the clause describing the requirement. The relevant information about requirements for specific xDSL system variants is given in annex A.

The splitter filter, as specified by the present document, may be implemented as an independent unit, separately from the xDSL transceiver, or may be integrated with the xDSL termination unit. The splitter may also be integrated with the base band termination unit (e.g. POTS line card); however this is outside of the scope of the present document.

# 2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

- For a specific reference, subsequent revisions do not apply.

- Non-specific reference may be made only to a complete document or a part thereof and only in the following cases:

    - if it is accepted that it will be possible to use all future changes of the referenced document for the purposes of the referring document;

    - for informative references.

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## 2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

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

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

[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".

## 2.2     Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area. For non-specific references, the latest version of the referenced document (including any amendments) applies.

[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]    ITU-T Recommendation G.993.1: "Very high speed digital subscriber line transceivers".

[i.8]    ITU-T Recommendation G.993.2: "Very high speed digital subscriber line transceivers 2 (VDSL2)".

[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]   ETSI TS 101 952-2: "Access network xDSL splitters for European deployment; Part 2: Generic specification of xDSL over ISDN splitters and xDSL universal splitters".

NOTE:    Part 2 of this multipart deliverable is under construction. Part 1 is the present document.

[i.13]        ETSI TS 101 952-3: "Access network xDSL splitters for European deployment; Part 3: Generic specification of distributed filters for xDSL over POTS";

NOTE:     Part 3 of this multipart deliverable is under construction. Part 1 is the present document.

[i.14]        ETSI TS 101 952-4: "Access network xDSL splitters for European deployment; Part 4: Additional specifications for dynamic distributed filters for xDSL over POTS".

NOTE:     Part 4 of this multipart deliverable is under study. Part 1 is the present document.

# 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 splitters:** splitters containing some active components, including splitters with "on/off-hook detection" circuitry

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

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:** splitter 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

**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].

**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 1:  See ES 203 021-3 [3].

NOTE 2:  In the case where multiple TEs are present at the customer end of the loop, then the TE is considered to be on-hook from the perspective of testing the splitter only when all of terminals are on-hook.

**passive splitters:** splitters containing exclusively passive components

**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

**signature network:** circuitry included at the POTS port of the splitter, the values and configuration of which may be operator dependent, which has the purpose of enabling network operator's remote line testing equipment to determine the presence of a splitter on a line

**xDSL:** ADSL or VDSL

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

## 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) |
| $C_{DCB}$ | DC Blocking capacitor as the optional high pass of first order |
| $C_{DSL}$ | 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 US(0) to DS edge for xDSL |
| $f_{M2}$ | intermediate frequency, used for IL in on-hook |
| $f_{Max}$ | maximum frequency above xDSL band for measurements |
| $IL_{DBOffH}$ | Insertion Loss xDSL Band Off-Hook |
| $IL_{DBOnH}$ | Insertion Loss (Isolation) xDSL Band On-Hook |
| $IL_{Meter}$ | Insertion Loss for Metering (Off-Hook) |
| $IL_{PBOffH}$ | Insertion Loss POTS Pass Band Off-Hook |
| $IL_{PBOnH}$ | Insertion Loss POTS Pass Band On-Hook |
| $IL_{TBOffH}$ | Insertion Loss Transition Band, only done in Off-Hook |
| LCL | Longitudinal Conversion Loss |
| LCTL | Longitudinal Conversion Transfer Loss |
| $L_{DSL}$ | The inductance L part of the $Z_{DSL}$ |
| $N_{DB}$ | Noise in the xDSL band |
| $N_{PB}$ | Noise in the POTS band (psophometric) |
| $R_{A\ to\ B\ wire}$ | DC resistance between A and B wire |
| $R_{DC}$ | DC Resistance of a splitter 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, option A or B |
| $R_{to\ Earth}$ | Resistance to Earth |
| $S_{DSL}$ | Switch to connect xDSL impedance $Z_{DSL}$ to the test set-up |
| UaE | Unbalance about Earth |
| $V_{RD}$ | 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 at the ringing frequencies |
| $Z_{ON}$ | 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 |
| $Z_{RefDSL}$ | Nominal Reference Design Impedance of xDSL ($Z_{RefDSL} \equiv R_{DSL}$) |
| $Z_{RHF}$ | Complex POTS impedance, extending $Z_R$ to higher frequencies, [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 $\Omega$ |

## 3.3 Abbreviations

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

| | |
|---|---|
| AC | Alternating Current |
| ADSL | Asymmetric Digital Subscriber Line |
| ADSL1 | ADSL limited to 1,1 MHz, see ITU-T Recommendation G.992.1 [i.9] |
| ADSL2 | ADSL revision 2, see ITU-T Recommendation G.992.3 [i.10] |
| ADSL2plus | ADSL revision "2plus", extended to 2,2 MHz; see ITU-T Recommendation G.992.5 [i.11] |
| AWGN | Additive White Gaussian Noise |
| CLIP | Calling Line Identification Presentation |
| CMRR | Common Mode Rejection Ratio |
| CO | Central Office ($\equiv$ Local Exchange $\equiv$ LE) |
| CPE | Customer Premise Equipment ($\equiv$ Terminal Equipment $\equiv$ TE) |
| DC | Direct Current |
| DS | Downstream, which is from LE side to TE side |
| DSL | Digital Subscriber Line |
| DSLAM | DSL Access Module, equipment at the LE side with multiple xDSL transceivers |
| DUT | Device Under Test |
| e.m.f. | Electro-Magnetic Force |
| F.F.S. | For Further Study |
| FDD | Frequency Division Duplexing |
| HPF | High Pass Filter |
| IL | Insertion Loss |
| ISDN | Integrated Services Digital Network |
| ITU | International Telecommunication Union |
| LE | Local Exchange ($\equiv$ Central Office) |
| N.A. | Not Applicable |
| NTP | Network Termination Point |
| POTS | Plain Old Telephone Service |

NOTE: The abbreviation POTS is used in the text of the present document instead of PSTN.

| | |
|---|---|
| PSTN | Public Switched Telephone Network |

NOTE: The abbreviation PSTN is replaced by POTS in the text of the present document.

| | |
|---|---|
| RL | Return Loss |
| RMS | Root Mean Square |
| SLIC | Subscriber Line Interface Circuit |
| SDSL | Symmetric DSL |
| TBD | To Be Determined |
| TE | Terminal Equipment (e.g. Telephone, Fax, voice band modem, etc.) |
| THD | Total Harmonic Distortion |
| UaE | Unbalance about Earth |
| US | Upstream, which is from TE side to LE side |
| US0 | US (Upstream) "0" band, the lowest VDSL upstream band |
| VDSL | Very high speed Digital Subscriber Line |
| VDSL1 | VDSL variant defined in ITU-T Recommendation G.993.1 [i.7] |
| VDSL2 | VDSL variant defined in ITU-T Recommendation G.993.2 [i.8] |

NOTE: xDSL is defined under clause 3.1 with definitions.

# 4        General functional description of xDSL over POTS splitters

The main purpose of the xDSL over POTS splitter is to separate the transmission of POTS signals and xDSL signals, enabling the simultaneous transmission of both services on the same twisted pair. The splitter also serves to protect POTS from interference due to 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 ADSL over POTS splitters is given in TR 101 728 [i.2]. Insertion of a splitter filter in existing POTS lines shall only have a low impact on the performance of the POTS service. A tutorial on the transmission and separation of POTS and xDSL signals is contained in annex I.

## 4.1        Functional diagram

The functional diagram for the splitter combination is given in figure 1.
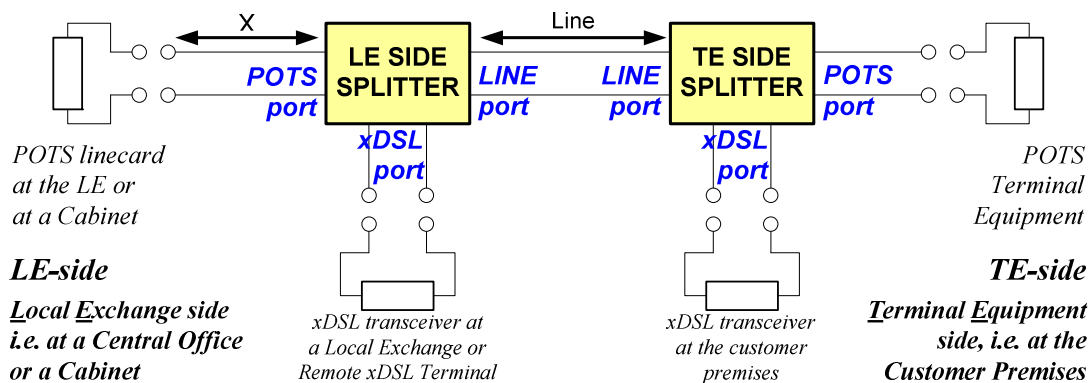


NOTE:        For a Local Exchange xDSL deployment, the length "X" in this figure will typically be far less than 1 km. For a remote xDSL terminal deployment, the length "X" can be up to several kilometres.

**Figure 1: Functional diagram of the xDSL splitter configuration**

The types of transfer functions between the different ports of the splitter are shown in figure 2 and can be understood as follows:

-        The transfer function from the POTS port to the LINE port and vice-versa is that of a low pass filter.

-        A high level of isolation is required from the xDSL port to the POTS port to prevent undesirable interaction between the xDSL transmission and any existing narrowband services, i.e. in both directions.

-        The transfer function from the xDSL port to the LINE port and vice-versa is either that of a high pass filter, or it may be all pass in nature, in the case where the full high pass filter function is implemented in the xDSL transceiver.
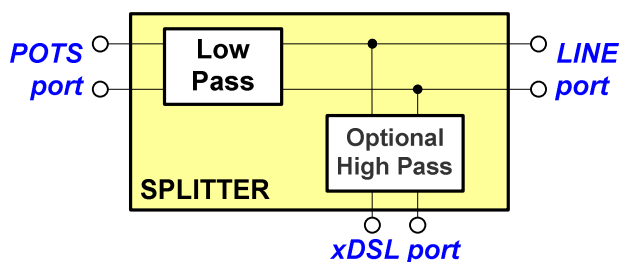


**Figure 2: Structure of the xDSL splitter filter**

## 4.2 High pass block: three alternatives

The optional high pass filter, as referred to in the present document, is the series high pass filter that is located in the splitter unit. It is distinct from the input high pass filter of the xDSL modem, which is located in the xDSL transceiver.

Reasons for including an optional series high pass filter in the LE splitter unit include the following:

- safety to uncouple the POTS line from damage due to the xDSL service;

- DC decoupling, to avoid "stealing" POTS service from the premises of an alternative operator;

- POTS privacy, when xDSL is supplied by an alternative operator, to avoid "listening".

At the TE/CPE side, the reasons above to install a series high pass filter are normally not applicable. The HPF provides DC de-coupling between the POTS and xDSL, and presents a more controlled impedance to the low pass filter at the xDSL port (e.g. it potentially enables the POTS service to continue functioning in the case of a user short circuiting the xDSL port of the splitter).

The high pass block shall be one of the following alternatives, detailed in clause 5.3:

- Alternative A: Absence of the series high pass filter in the splitter unit.

- Alternative B: First order filter made up of two DC blocking capacitors.

- Alternative C: Higher order filter (not completely specified in the present document).

Implementation requirements for alternatives B and C are given in clause 5.3.

Electrical requirements are given in clause 6.

# 5 Circuit definitions, testing conditions and methods

## 5.1 DC testing conditions

### 5.1.1 Polarity independence

The splitter 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.

This may not apply in the case where a "signature network" is used, as this may be polarity dependant. For the definition of a signature network, see clause 3.1.

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

The electrical requirements in the present document can be classified as follows:

- On-hook requirements, when all POTS terminals are in the on-hook state.

- Off-hook requirements, when a 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 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 MΩ 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 splitter. In this case an impedance model of $Z_{OnLI}$ is used to terminate the LINE and POTS port of the splitter 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 are F.F.S. (for further study). Tests for transitional requirements are introduced in clause 6.13. However, this clause is for information only. Most likely the WT-127 of the Broadband forum will provide the methodology to test this aspect of splitters. A tutorial text on WT-127 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 figures 3 and 4. For balance C1 ≡ C2 and L1 ≡ L2.
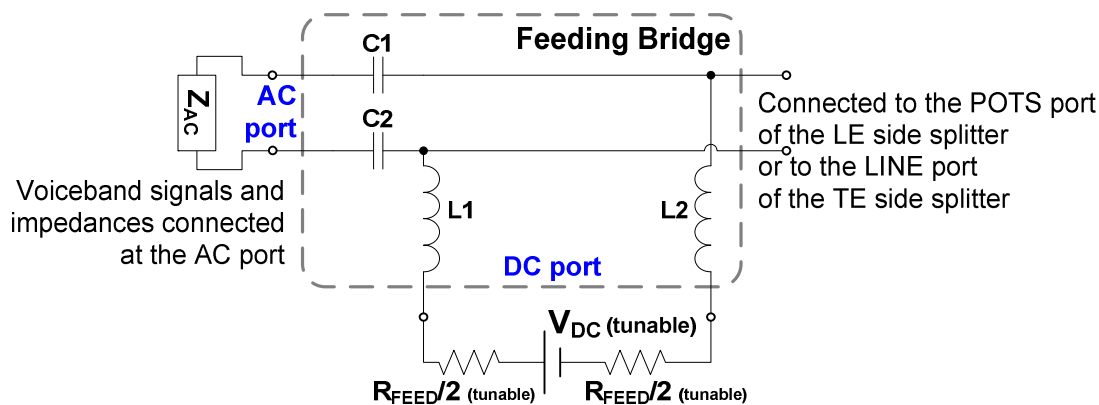


**Figure 3: Feeding Bridge**
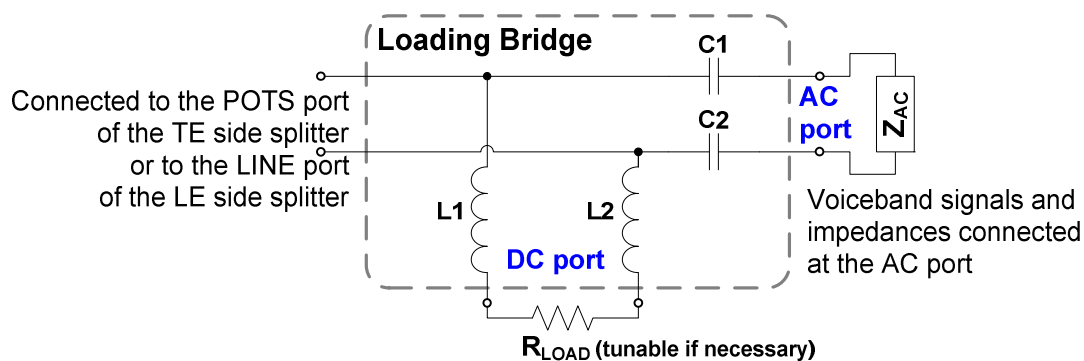


**Figure 4: Loading Bridge**

NOTE 1: It is necessary to combine these feeding and loading bridges with the splitter test circuit diagrams of clauses 5.4 to 5.7. How this is done, is one aspect of the documents [i.3], [i.4], [i.5] and [i.6], which were already mentioned in the foreword in note 2. However, to clarify the combination of feeding and loading bridges with the diagrams of clause 5.4, a few examples are also shown in the informative annex G.

NOTE 2:    The properties of the feeding and loading bridges should be sufficiently good, to prevent that measurements of splitter properties are affected by these bridges. E.g. in note 2 of clause 5.5.3 it is stated that their balance should be sufficiently good. 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.

# 5.2    AC terminating impedances $Z_{AC}$

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 $Z_{DSL}$, xDSL transceiver related impedances

In many of the tests the xDSL port of the splitter is terminated with impedances called $Z_{RefDSL}$ and $Z_{DSL}$. $Z_{RefDSL}$ is the nominal design impedance of the xDSL 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 splitter when verifying certain requirements. These models are intended for splitter specification in the context of the present document. The purpose of these model impedances is for splitter 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.

NOTE:    The load $Z_{DSL}$ at the xDSL port differs, depending on the order of the high pass section defined in clause 5.3. This is explained in clause A.1. The total xDSL load seen at the LINE port due to $Z_{DSL}$ and the optional high pass should be identical for a splitter without a high pass or for one with a first order high pass, i.e. the DC two blocking capacitors of clause 5.3.1.

## 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 **S**hort **L**ine terminated in 600 Ω and is shown in figure 6.
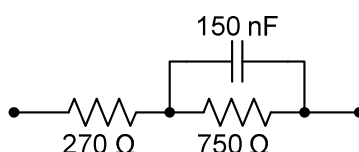


**Figure 5: Impedance $Z_R$**
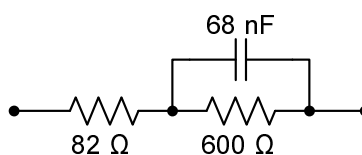


**Figure 6: Impedance $Z_{SL}$**

NOTE:    In the case of splitters to be deployed in some networks, alternative models of reference impedances instead of $Z_R$ may be used when testing according to the splitter 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 splitter. This is the European harmonized complex impedance $Z_R$ with the modification for **H**igh **F**requencies proposed in TR 102 139 [i.1]. This network is shown in figure 7.
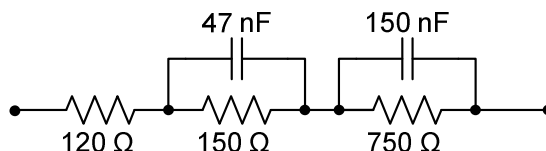
**Figure 7: Impedance $Z_{RHF}$**

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, 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 splitters. It is not intended to be an equivalent circuit for a POTS TE.
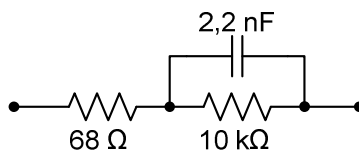
**Figure 8: Impedance $Z_{OnHI}$**

## 5.2.5    $Z_{OnLI}$, on-hook low impedance

For some on-hook requirements, as defined in clause 5.1.2, 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.

Actual impedances can vary greatly and thus the impedance model adopted here is just intended for the verification of splitters. $Z_{OnLI}$ shall be 600 Ω.

   NOTE:     This $Z_{OnLI}$ emulates a scenario in which the TE changes its on-hook impedance when receiving CLIP to $Z_R$ or a similar low-Ohmic impedance.

## 5.2.6    $Z_{OnHo}$, impedance on-hook

To model multiple on-hook telephones in parallel with a single off-hook phone, $Z_{OnHo}$ is used. It was shown that the $Z_{OnHI}$ is inappropriate, due to its low impedance, which is a worst case situation. $Z_{OnHo}$ is not used in the present document. It is added for completeness. It is used for testing multiple parallel distributed filters in TS 101 952-3 [i.13] and TS 101 952-4 [i.14] (see foreword).
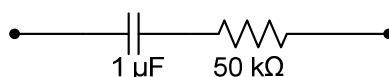
**Figure 9: Impedance $Z_{OnHo}$**

## 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, the terminating POTS impedance $Z_{Ring}$ is used, modelling the terminal equipment on-hook. This impedance represents the minimum ringing load of the customer premises equipment that any network is assumed to be able to support. The $Z_{Ring}$ impedance is dependent on the ringing frequency. The circuits in the following figure apply:



$Z_{Ring}$ 50 Hz — 1 µF 2,7 kΩ

$Z_{Ring}$ 25 Hz — 2,2 µF 2,7 kΩ
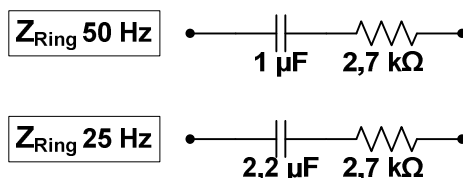
**Figure 10: Impedances $Z_{Ring}$ for 25 and 50 Hz ringing**

## 5.2.8 $Z_{Meter}$, impedance of the metering device

To model the metering device tuned to 12 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.

# 5.3 High pass filter implementation

As stated in clause 4.2, the high pass block shall be one of the following alternatives:

- Alternative A: Absence of the series high pass filter in the splitter unit; this means that the LINE port and the xDSL port are identical and connected without any intermediate devices in between them.

- Alternative B: First order filter made up of two DC blocking capacitors.

- Alternative C: Higher order filter.

## 5.3.1 High pass filter alternative B: First order filter

DC Blocking capacitors $C_{DCB}$, as shown in figure 11, shall make up the first order high pass filter.



LINE port  $C_{DCB}$  $C_{DCB}$  xDSL port
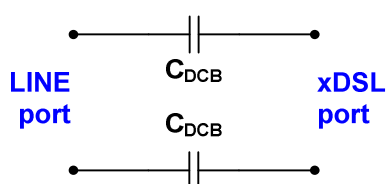
**Figure 11: Implementation of a first order high pass filter**

A tolerance of 5 % shall be allowed for the practical implementation of these capacitors across the frequency range. They shall be capable of withstanding the DC conditions of clause 5.1.2 and the AC ringing voltages of clause 6.3.3. Nominal values of $C_{DCB}$ are listed in clause A.1 for different xDSL variants. The balance test of the high pass in clause 6.8.2 allows to test the matching of the two $C_{DCB}$ capacitors. The potentially excessive loss caused by these capacitors (as compared with the reference high pass of clause 5.3.3) on the xDSL signal is measured with the $Att_{DB}$ of clause 6.9.4.

## 5.3.2     High pass filter alternative C: higher order filter

The third order high pass filter as defined in figure 12 shall make up the equivalent circuit diagram of an alternative C high pass filter. This implementation shall only be considered as an example, as other realizations of this circuit are allowed, e.g. including a Galvanic separation with transformers.
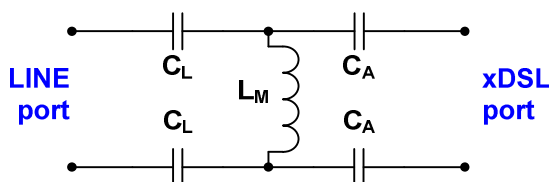


**Figure 12: Implementation of 3$^{rd}$ order high pass filter**

The tolerance for the practical implementation of the capacitors and the inductor are F.F.S.

The impedance network presented in figure 12 is an electrical representation, rather than a circuit diagram. The actual implementation shall present an impedance over the xDSL frequency band equivalent to that shown in figure 12.

> NOTE:     The electrical representation given in figure 12 is considered to be a satisfactory implementation of the higher order filter. Alternative implementation methods are F.F.S. For example, for ADSL or for VDSL with a US0 band the following values for the electrical representation could be used: $C_L$ = 54 nF, $C_A$ = 90 nF, $L_M$ = 0,38 mH.

## 5.3.3     Reference high pass filter

The reference high pass is composed of two DC blocking capacitors, with 5 % tolerance on the absolute value and a matching better than 1 %. E.g. for ADSL and ADSL2 the DC blocking capacitors are 120 nF each. Details in clause A.1.

The reference high pass filter is used in the reference case of the IL measurements from LINE port to xDSL port of clause 5.4.4, when the splitter contains the optional high pass filter alternative B or C (of clauses 5.3.1 or 5.3.2).

If the splitter contains no high pass part (alternative A above), then the reference high pass shall be a short circuit, as detailed in clause 5.4.4, as shown in figure 17.

## 5.4     General transmission test set-up

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.

**Insertion Loss (IL):**

To measure the propagation of certain signals with little loss or with some desirable strong attenuation between one port of the splitter to another port of the splitter the measurement of the Insertion Loss (IL) is used in most cases.

**Return Loss (RL):**

Another important property of the splitter 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 splitter is inserted, when that impedance is measured at another port of the splitter. 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 splitter fulfils the IL, RL and other requirements, in clauses 6.4, 6.5, 6.6, 6.7, 6.11.1 and 6.12 with and without the xDSL load $Z_{DSL}$ connected to the splitter. The requirements specified in clauses 6.3, 6.8, 6.9, 6.10, 6.11.2, 6.13 and 6.14 are only measured in the presence of $Z_{DSL}$.

## 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 splitter attenuates a signal very little, e.g. between the LINE and the POTS port in the POTS band. IL can also indicate that a splitter 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 splitters** 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 splitter 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 splitter in the xDSL band, which is undefined.

## 5.4.2        POTS signal loss: IL LINE port to POTS port

To measure the loss effect on the POTS signals resulting from the insertion of the splitter in the POTS path, the insertion loss is measured between the LINE port and the POTS port. Note that for measuring the insertion loss of the low pass part of a splitter, the measurement is done for the splitter alone and for the combination of the splitter with the xDSL impedance terminating its xDSL port.

For measurements of the Insertion Loss (IL) from the LINE port to the POTS port and for the inverse, the test set-ups are given in figures 13 and 14. These IL measurements are done with the switch $S_{DSL}$ either open or closed, i.e. with the xDSL impedance $Z_{DSL}$ absent or present. The IL is measured over the relevant POTS frequencies, such as the voice band and the metering frequencies.
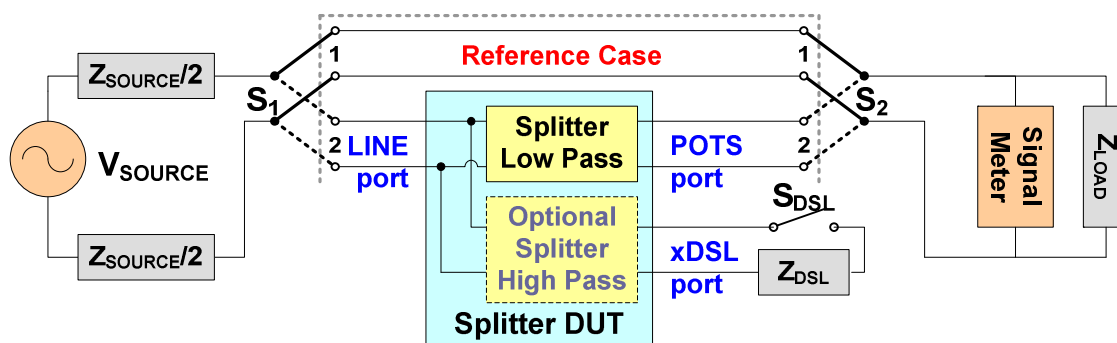


**Figure 13: Test set-up for Insertion Loss from LINE port to POTS port**
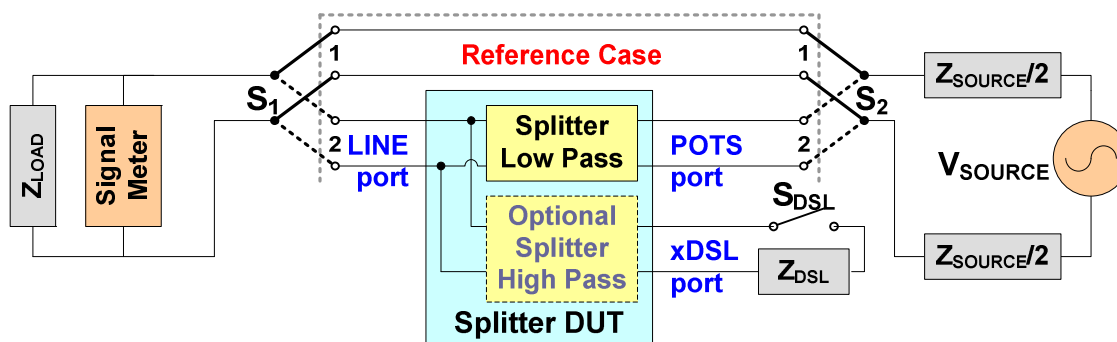


**Figure 14: Test set-up for Insertion Loss from POTS port to LINE port**

NOTE:     The IL measurement with the switch $S_{DSL}$ closed will not represent the IL of the splitter low pass 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 shown. 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, as explained in the same annex D.

## 5.4.3      xDSL signal isolation: IL LINE to POTS port or xDSL to POTS port

To measure the isolation caused by the splitter low pass section in the xDSL band, the loss effect resulting from the splitter insertion must be measured. The isolation can be measured between the LINE port and the POTS port and between the xDSL port and the POTS port, and in the opposite direction between the POTS port and the LINE port and between the POTS port and the xDSL port.

For the measurement of the isolation from LINE port to POTS port or from POTS port to LINE port the Insertion Loss is measured with the set-up of the previous clause. However, in this case the switch $S_{DSL}$ is 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.

Besides the measurement from POTS port to LINE port (or vice versa), one can generate a signal at the POTS port, and measure at the xDSL port or generate a signal at the xDSL port and measure at the POTS port. However, for xDSL over POTS splitters **these additional measurements are not required, because** the IL of the low pass section between POTS port and xDSL port is virtually identical to the IL of the low pass section from POTS port to LINE port. Note also that, if the optional high pass is absent, there is no difference between the LINE port and the xDSL port.

NOTE:     Identically to the previous clause the $Z_{DSL}$ is not present during the reference measurement. Therefore the IL of the splitter low pass is increased by the additional loss caused by the $Z_{DSL}$.

## 5.4.4      xDSL signal loss: IL LINE port to xDSL port

The final transmission tests are needed to measure the attenuation effect of the high pass and the low pass section on the xDSL signals, which normally transit from the LINE to the xDSL port, or in the inverse direction.

These transmission related tests require a signal to be generated at the xDSL port and measured at the LINE port and also a signal to be generated at the LINE port and measured at the xDSL port. It would appear that these last two tests are merely testing the high pass part of the splitter, which is a set of capacitors with known values. However, these tests performed via the (known) high pass filter must be done in the presence of the low pass filter, to prove that this low pass filter does not affect the xDSL signals unnecessarily, i.e. does not attenuate, distort or add noise. Additionally, the test in this clause will also identify a defective high pass, with too much IL from LINE port to xDSL port.

NOTE 1:  In previous versions of the splitter documents (including the documents [i.4] and [i.6]) it has never been clear how to measure correctly the effect on the xDSL signals caused by the presence of the low pass. The measurement could be done at the LINE port or the xDSL port of the splitter or at the $Z_{RefDSL}$ ($R_{DSL}$) impedance inside the $Z_{DSL}$. In fact, the measurement of the IL of the low pass section can be done at either position, with identical results. Furthermore, note that in [i.4] and [i.6] it was required to measure the IL using a reference situation without both high pass and low pass. This will measure the IL between LINE and xDSL ports due to both high pass and low pass. This is not a relevant measurement, because the high pass of the splitter is conceived such that the capacitors of the splitter high pass (e.g. $C_{DCB}$ = 120 nF) and the high pass filter at the entrance of $Z_{DSL}$ (containing $C_{DSL}$) are always in series. Therefore, it is irrelevant to use a reference measurement in which the optional splitter high pass is absent.

The theoretical set-up of the IL from the LINE port to the xDSL port (with identical values for the inverse direction, due to the passive nature of the high pass circuit) is as shown in figure 15. (The reference case has the low pass and its load impedance at the POTS port removed. This is equivalent to opening switch $S_1$.)
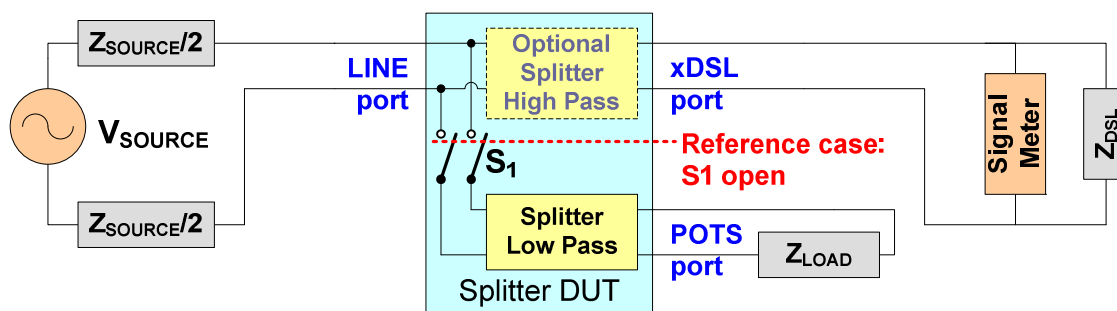
**Figure 15: Theoretical test set-up for Insertion Loss from LINE port to xDSL port**

NOTE 2:  The load $Z_{DSL}$ at the xDSL port differs, depending on the order of the high pass section, see clauses 5.3 and A.1.

The IL caused by the low pass requires a switch inside the splitter, which is not available. Therefore, the following practical variant of the IL test shall be used, in which the complete splitter is removed, but in the reference case a reference high pass is inserted identical to alternative B of the splitter high pass (clause 5.3), as shown in figure 16.
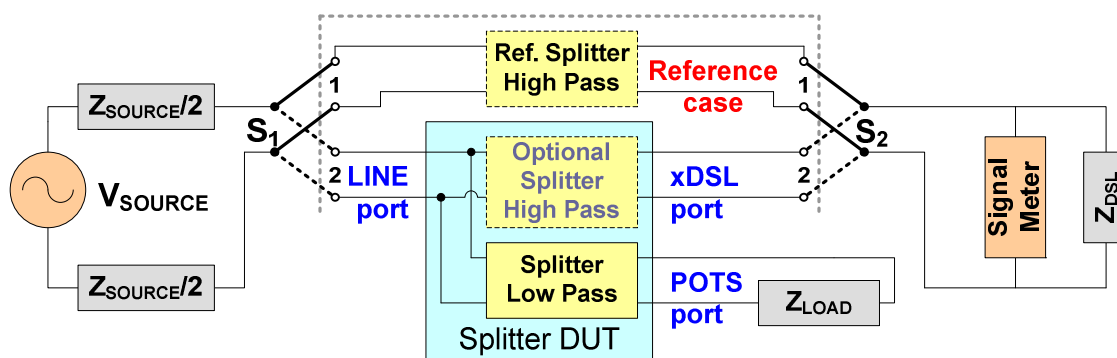


**Figure 16: Practical test set-up for Insertion Loss from LINE port to xDSL port**

The reference high pass is defined in clause 5.3.3.

If the splitter contains no high pass part, i.e. alternative A of clause 5.3, then the reference high pass shall be a short circuit, as shown in figure 17.
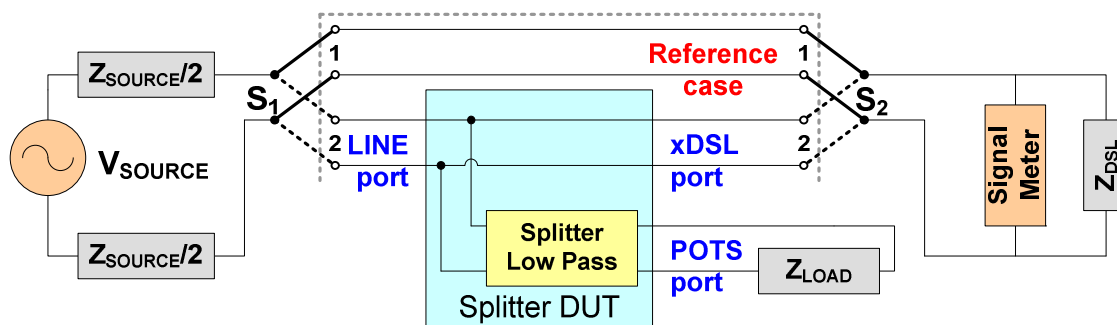


**Figure 17: Test set-up for IL from LINE port to xDSL port, for alternative A, i.e. without HPF section**

If the high pass is according to alternative C (i.e. higher in order), the same reference splitter high pass composed of two DC blocking capacitors shall be used. This allows to measure the additional loss effects of the higher order high pass by comparing its loss with the loss of the first order reference high pass.

NOTE 3:  The insertion loss could also be measured from xDSL port to LINE port, according to figure 18, but for passive splitters this will result in identical results, as stated e.g. in note 1 in clause 5.4.1.
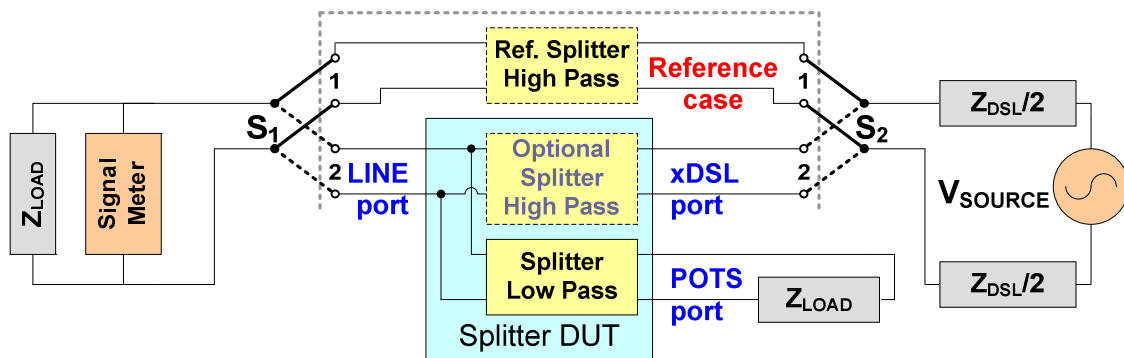
**Figure 18: Practical test set-up for Insertion Loss from xDSL port to LINE port**

NOTE 4:   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 Ω impedance in the $Z_{LOAD} = Z_{DSL}$, but this would result in a more complicated set-up that e.g. can be found in [i.4] and [i.6], with identical results. The relevant diagrams are added in the informative annex E.

The load $Z_{LOAD}$ at the POTS port in figures 15 to 18 shall be modelled as a short circuit, an open circuit and some relevant POTS reference impedances such as $Z_{RHF}$.

NOTE 5:   Loading the POTS port of the low pass section of the splitter 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 loose synchronization. This can be checked with the WT-127 methodology as described in the note in clause 6.9.4.1. The whole WT-127 based methodology is still F.F.S.

## 5.4.5    General definition of the Return Loss

The measurement of the Return Loss (RL) of a splitter 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 splitter 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 Ω. 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 splitters 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.

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

NOTE:   For splitters the RL is measured in the presence and absence of the xDSL service. This means that the RL is measured for either the splitter 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 must be measured in the presence and absence of the xDSL service, i.e. with $Z_{DSL}$ both connected and removed by acting on the switch $S_{DSL}$.

For the purpose of measuring RL of splitters, $Z_{LOAD}$ is used as $Z_{Ref}$ in the general formula, as shown in the formulae in figures 19 and 20. In this way the "transparency" of the splitter can be appreciated.

$$RL = 20 \cdot \log \left( \frac{|Z_{LOAD} + Z_{IN}|}{|Z_{LOAD} - Z_{IN}|} \right)$$
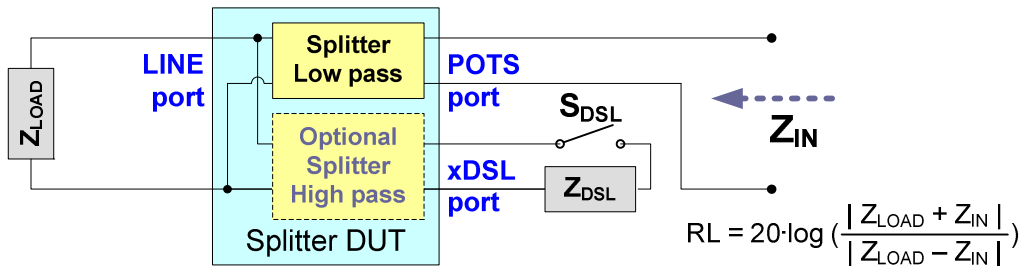
**Figure 19: Definition of Return Loss at the POTS port**

$$RL = 20 \cdot \log \left( \frac{|Z_{LOAD} + Z_{IN}|}{|Z_{LOAD} - Z_{IN}|} \right)$$
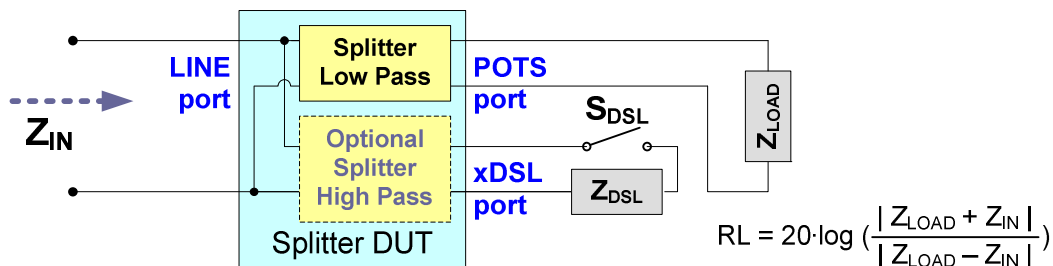
**Figure 20: Definition for Return Loss at the LINE port**

For the practical realization of the RL measurements practical bridge-based circuit diagrams are included in annex F.

## 5.5 Unbalance measurement

An additional property of a splitter 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 splitter 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 21. The xDSL port is terminated with a balanced $Z_{RefDSL}$ impedance.

In the case of measuring at the LINE port with the termination at the POTS port, the test set-up of figure 22 is used, which is derived from figure 21 by reversing the POTS and LINE ports. For measuring at xDSL port, terminating at the LINE port, figure 23 is used. For measuring at LINE port, terminating at the xDSL port, figure 24 is used. The remaining third port is terminated with the appropriate balanced impedance as shown.

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 150 Ω impedance should be used in series with the longitudinal source (i.e. $S_1$ in figures 21 to 24 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 21. In figures 22 to 24 use $U_T$ for LCL.).

$$Unbalance = 20 \log_{10} \left| \frac{U_0}{U_T} \right| \qquad (dB)$$
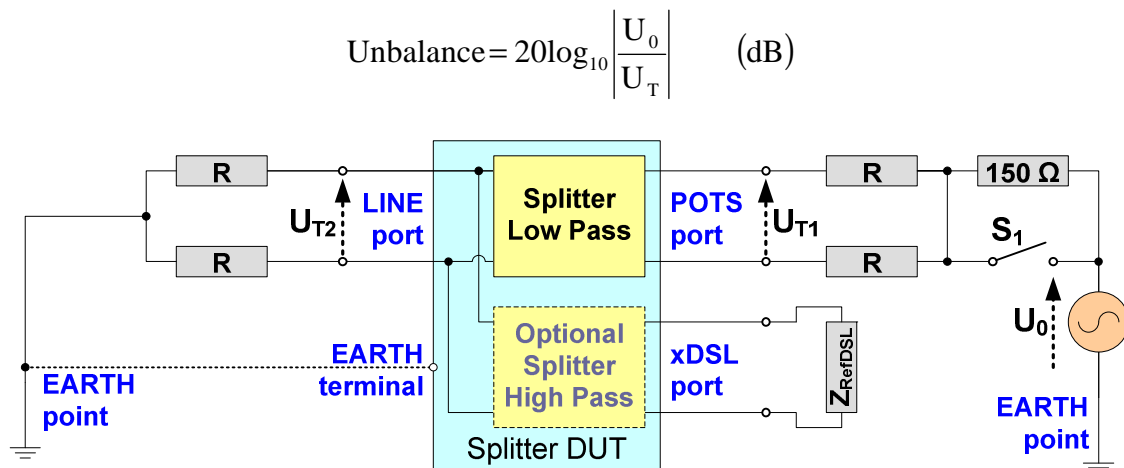


**Figure 21: UaE; LCL or LCTL measurement test set-up POTS port to LINE port**

All notes apply to the figures 21 to 24.

NOTE 1:   The 150 Ω models the longitudinal impedance of the line or of the POTS circuits.

NOTE 2:   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], [i.4], [i.5] and [i.6], 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 3:  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 4:  The dotted connection is only used if the splitter has an earth terminal.

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

NOTE 6:  If the splitter has no earth terminal, the test should be performed with the splitter placed on an earthed metal plate of a sufficiently large size.
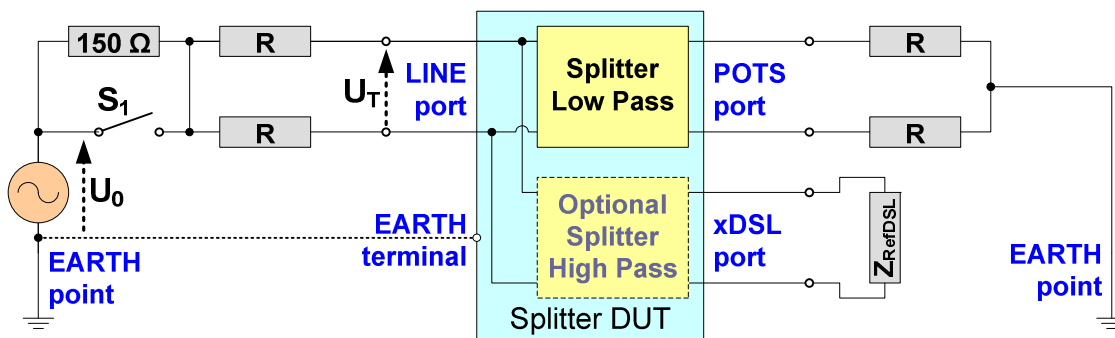
**Figure 22: UaE; LCL measurement test set-up LINE port to POTS port**
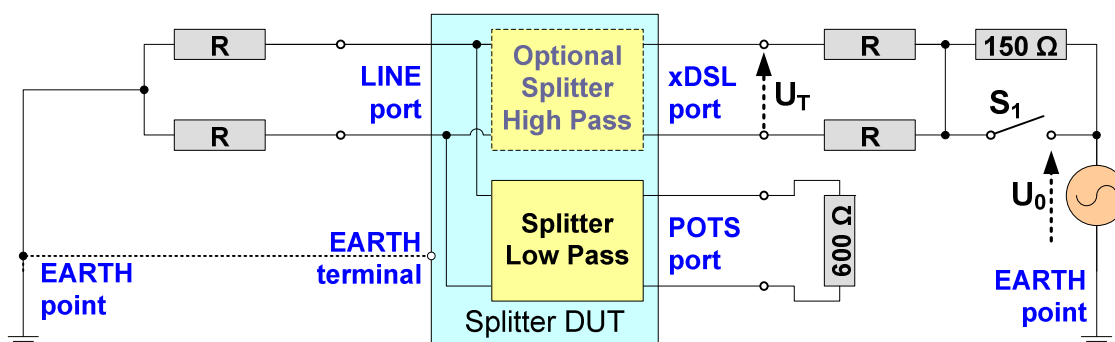
**Figure 23: UaE; LCL measurement test set-up xDSL port to LINE port**
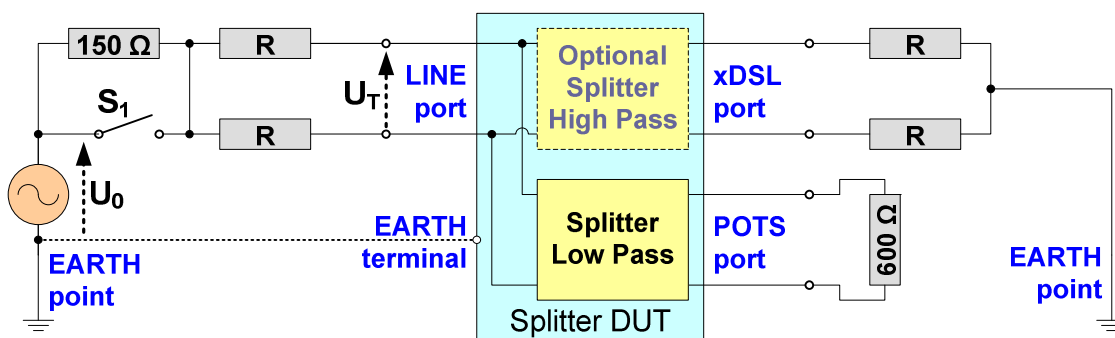
**Figure 24: UaE; LCL measurement test set-up LINE port to xDSL port**

# 5.6    Noise measurement

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

## 5.6.1    Psophometric noise in the POTS Band

The methodology for testing noise of active/dynamic splitters 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 splitters is F.F.S. and it is introduced in the informative annex K.

# 5.7    Common Mode Rejection Ratio measurement

Normally a splitter serves as a shield for the xDSL modem by suppressing the differential mode noises, which are present on the POTS network in the user premises. However, also a common mode noise could be picked up on the POTS network. This common mode noise might pass the splitter low pass section without any required attenuation. The common mode noise then reaches the xDSL modem and the telephone line where it will be partially converted into differential mode noise signals, which will enter the xDSL transceiver input stage and affect the xDSL transmission.

Therefore, splitters with the ability to suppress common mode signals will reduce the effects of these noises on the xDSL modem and will improve the xDSL signal transmission.

The test set-up for measuring the Common Mode Rejection Ratio (CMRR) of the splitter is in given figure 25.

The test can be carried out in different directions:

- from the POTS port to the LINE port, or from the LINE port to the POTS port, i.e. in the opposite direction;

- from the POTS port to the xDSL port, or from the xDSL port to the POTS port, i.e. in the opposite direction.

There is no CMRR measurement from the xDSL port to LINE port, neither is there one in the opposite direction. The port that is not used during the measurement is left open.
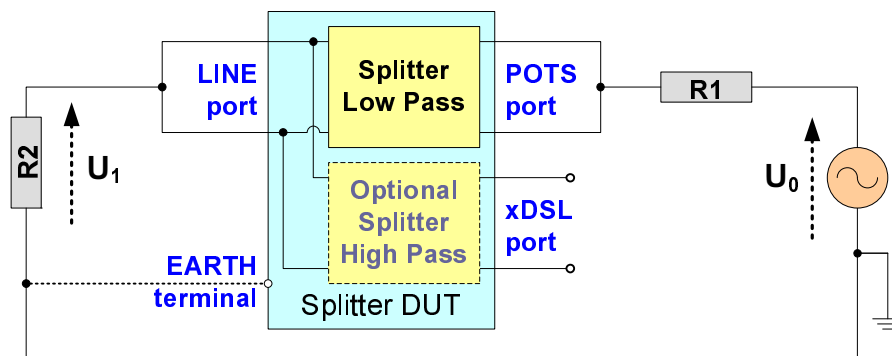


**Figure 25: Test set-up for measuring the CMRR from POTS to LINE port**

The CMRR is calculated according to the following formula:

$$CMRR = 20 \times \log (U_0 / U_1) \ (dB)$$

# 6    Splitter requirements

# 6.1    Options for splitter requirements

The reference impedance requirements of European networks vary. Some networks have a single fixed impedance, other networks have various impedances. When designing for single impedance networks it is possible to optimize the splitter design for that specific impedance. It is possible with some added complexity to achieve this level of optimization for a network with various impedances, but it is not very practical.

In order to allow single impedance networks to benefit from the increase in achievable performance, while not limiting the use of existing impedances present in other networks it has become necessary to create two separate options.

Option A specifications (see clause 6.1.1) are agreed based on what is reasonably achievable when designing for networks with various impedances.

Option B specifications (see clause 6.1.2) are agreed based on what is reasonably achievable when optimizing for networks with a single impedance.

It is recognized that some network providers desire splitters that achieve some or all of the higher specifications in the POTS band for Option B while retaining the flexibility in POTS impedance and the stronger isolation in the xDSL band of Option A. Such enhanced splitters would be more complex and are not covered by the present document.

In a practical sense, the requirements for Option A and Option B are identical with the exception of two clauses: clause 6.6 specifying pass band return loss requirements in the off-hook state, and clause 6.9.2 concerning off-hook isolation.

## 6.1.1    Option A splitters

NOTE:    Option A is appropriate for networks where the terminals and LE variants have several different reference impedance values (e.g. 600 Ω, harmonized European reference impedance $Z_R$ and other complex impedances), and one single reference impedance is insufficient to accommodate the needs of all terminals and LE variants. Option A splitters have the potential for increased degradation of POTS service when compared to Option B splitters.

- Option A splitters shall meet return loss requirements for two reference impedances, which is appropriate for networks where the population of existing terminals or network presentations includes equipment designed against several different reference impedance values.

- Conversely, this option assumes that potential sidetone and far end echo effects can be adequately accounted for with relatively moderate return loss requirements.

- In addition, option A splitters are considered to be appropriate to networks where concerns of potential interference between services (e.g. audible xDSL interference to the POTS service) necessitate very high levels of isolation.

## 6.1.2    Option B splitters

NOTE:    Option B is appropriate for networks that have one single reference impedance for all terminals and local exchanges.

- Option B splitters are considered to be appropriate to networks where concerns of sidetone and far end echo effects motivate a very high return loss requirement.

- Additionally, this Option B return loss requirement shall be met for one reference impedance, and thus option B splitters are appropriate for networks for which it is felt that one single reference impedance is sufficient to accommodate the needs of all terminals and network presentations.

- Conversely, this option assumes that potential interference between services can be adequately accounted for with lower isolation requirements than Option A.

# 6.2    DC requirements

## 6.2.1    DC resistance to earth

The DC resistance $R_{to\ Earth}$ between each line terminal (i.e. A-wire and B-wire) of the splitter and earth, when tested with 100 V DC, shall not be less than 20 MΩ.

This requirement only applies to splitters with a direct connection to earth.

NOTE:    This requirement takes into account the minimum total DC Resistance to earth that is acceptable for TE complying with ES 203 021-3 [3]. It is recognized that the majority of passive splitters will achieve DC Resistance to earth of at least 100 MΩ. It is also recognized that having a DC resistance to earth value of this magnitude is an important issue for network operators to facilitate routine testing of access network plant.

## 6.2.2    DC insulation resistance between A-wire and B-wire

The DC resistance $R_{A\ to\ B\ wire}$ between the A-wire and B-wire at both the LINE and POTS port of the splitter, when tested with 100 V DC, shall not be less than 5 MΩ.

NOTE 1:  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 will achieve DC Resistance between A and B wires of at least 20 MΩ.

NOTE 2:  In the case where the splitter is fitted with a signature network, measurement of the DC isolation resistance becomes more difficult. Possible solutions include a switching system in order to open circuit the signature network for the measurement, or indeed performing the measurement before the signature network is added to the splitter card. It is left to the individual operator to determine how this measurement should be carried out. Depending on the particular test methodology used, the requirement should be adjusted accordingly.

## 6.2.3    DC series resistance $R_{DC}$

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.

## 6.2.4    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 splitter ports will normally be lower depending on the characteristics of the terminal and the feeding bridge and on the line length.

The splitter 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]).

- Polarity reversal (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 preferred in combination with xDSL.

- K-break referred to in ES 201 970 [6], clause 14.6.

- Alerting for CLIP and other enhanced signalling, according to parts 1 and 2 of both EN 300 659 [7] and ES 200 778 [8].

- ES 200 778 [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 corresponding clauses 6.3.1 and 6.3.3.

## 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 splitter is tested in one direction only, according to the test set-up of figure 13 for the splitter at the TE side **or** of figure 14 for the splitter at the LE side. It shall be not more than $V_{RD}$ (abbreviation of $V_{Ring-Drop}$), which has a value of 2 Volt. This requirement shall be tested for the worst capacitive load, i.e. with the switch $S_{DSL}$ in figures 13 and 14 closed.

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

| Signal source Impedance | 850 Ω (resistive) |
|---|---|
| Load Impedance, dependent of the ringing frequency | $Z_{Ring}$ (as defined in clause 5.2.7) |
| AC test signal source e.m.f. | 35 $V_{RMS}$ |
| DC feeding voltage | 60 V DC |

## 6.3.2    $Z_{InRing}$ impedance in the presence of ringing at 25 Hz and 50 Hz

The POTS port and the LINE port of the splitter shall have an impedance $Z_{InRing}$ (when measured between the A-wire and the B-wire) at 25 Hz greater than 40 kΩ or at 50 Hz greater than 36 kΩ if applicable. When testing at either the POTS port or at the LINE port, all other ports shall be kept open circuited.

> NOTE:    A splitter with an impedance of 40 kΩ will typically draw only 1/10 of the current of a reference ringer load of 4 kΩ. A waiver should be considered for minor violation of the 36 kΩ value at 50 Hz for splitters that try to achieve a strong rejection in the xDSL band.

## 6.3.3    Total harmonic distortion at 25 Hz and 50 Hz

The splitter 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 specified in table 2. The test shall be carried out at 25 Hz and at 50 Hz. With these voltages applied, the total harmonic distortion ($THD_{Ring}$) of the AC signal shall be less than 10 %. The test set-up is shown in figure 13 for the TE side splitter and in figure 14 for the LE side splitter. This requirement is needed to protect the xDSL transmission and therefore, it shall be met with the switch $S_{DSL}$ in figures 13 and 14 closed.

**Table 2: Test conditions for $THD_{Ring}$ at 25 Hz and 50 Hz**

|  | test 1 | test 2 |
|---|---|---|
| AC test signal source e.m.f. | 100 $V_{RMS}$ | 50 $V_{RMS}$ |
| DC feeding voltage | 50 V DC | 78 V DC |
| Signal source frequency | 25 Hz and 50 Hz | |
| Signal source impedance | 850 Ω (resistive) | |
| Load impedance, dependent of the ringing frequency | $Z_{Ring}$ (as defined in clause 5.2.7) | |

> NOTE:    Additionally, the WT-127 (see annex H) test methodology will demonstrate the effects of the harmonic distortion on the xDSL transmission. With WT-127 one would measure the distortion caused by splitters indirectly, by checking how worst case ringing signals (applied continuously via the splitter DUT) do affect the margin or the bitrates in US and DS of the xDSL. A worst case load of parallel impedances $Z_{Ring}$ (or its equivalent) should be used. The whole WT-127 based methodology is still F.F.S.

## 6.4    POTS pass band loss requirements (on-hook)

All requirements of IL for passive splitters need to be measured in one direction only.

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

The IL of the splitter 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 test needs to be done in one direction only, e.g. according to figure 13 for the TE side splitter and in figure 14 for the LE side splitter. This requirement shall be met with the switch $S_{DSL}$ in figures 13 and 14 both open and closed. The on-hook DC feeding conditions are specified in clause 5.1.2.

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

**Table 3: Impedances and test set-ups for the on-hook pass band loss test**

| Splitter Type | Test set-up reference | Impedance of signal source | Impedance of the load (modelling line + phone) | DC feeding voltage |
|---|---|---|---|---|
| LE side | Figure 14 | $Z_R$ (POTS port) | $Z_{OnHI}$ (LINE port) | See clause 5.1.2 |
| TE side | Figure 13 | $Z_R$ (LINE port) | $Z_{OnHI}$ (POTS port) | See clause 5.1.2 |

Level of the test signal = -4 dBV e.m.f. $Z_R$ and $Z_{OnHI}$ are defined in clauses 5.2.2 and 5.2.4.

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

The requirements of this clause are only applicable to certain networks (see clause 5.1.2). The on-hook pass band insertion loss and loss distortion shall be measured in one direction only, e.g. according to figure 13 for the TE side splitter and according to figure 14 for the LE side splitter.

In both cases, both the source and load impedance shall be $Z_{OnLI}$. This requirement shall be met with the additional required on-hook DC feeding conditions stated in clause 5.1.2, i.e. with a current from 0,4 mA to 2,5 mA.

This requirement shall be met with the switch $S_{DSL}$ in figures 13 and 14 both open and closed.

### 6.4.2.1      Low impedance on-hook POTS pass band insertion loss

The insertion loss of one splitter at 1 kHz in the POTS band while on-hook ($IL_{PBOnH}$) shall be less 1 dB.

### 6.4.2.2      Low impedance on-hook POTS pass band insertion loss distortion

The absolute difference between the insertion loss at any frequency in the range 200 Hz to 2,8 kHz and the insertion loss at 1 kHz shall be less than 1 dB.

## 6.5      POTS pass band loss requirements (off-hook)

The test set-ups are given in clause 5.4.2. The test needs to be done in one direction only. The off-hook pass band IL shall be measured according to figures 13 **or** 14 for both the LE side and the TE side splitter. The off-hook DC feeding conditions are specified in clause 5.1.2. The level of the test signal shall be -4 dBV e.m.f. The test shall be executed with both combinations of source and load impedances as presented in table 4.

**Table 4: Combinations of source and load impedances for the pass band loss requirements**

| Source/Load combination | Impedance of the signal source | Impedance of the load |
|---|---|---|
| Combination 1 | $Z_R$ | $Z_R$ |
| Combination 2 | 600 Ω | 600 Ω |

The requirements in this clause shall be met with the switch $S_{DSL}$ in figures 13 and 14 both open and closed.

### 6.5.1    Off-hook POTS pass band insertion loss

The insertion loss at 1 kHz in the POTS band while off-hook ($IL_{PBOffH}$) of one splitter shall be less than 1dB.

### 6.5.2    Off-hook POTS pass band insertion loss distortion

The absolute difference between the insertion loss at any frequency in the range 200 Hz to 4 kHz and the insertion loss at 1 kHz shall be less than 1 dB.

## 6.6       POTS pass band return loss requirements (off-hook)

The return loss (RL) at both the POTS and LINE port of the splitter shall be measured according to clause 5.4.6, and figures 19 and 20, i.e. **at both ports**. The return loss requirements shall be met with the switch $S_{DSL}$ both open and closed. As shown in figures 19 and 20 $Z_{LOAD}$ shall be connected with appropriate values, as indicated specifically for both options in the corresponding clauses 6.6.1 and 6.6.2.

There are two options for return loss testing: option A and option B as explained in clause 6.1. The following requirements are equally applicable to the LE side and TE side splitters. Return loss testing is to be carried out with the off-hook DC feeding current conditions specified in clause 5.1.2.

The pass band return loss requirements in the off-hook condition are POTS related and not depending on the type of xDSL.

### 6.6.1    POTS pass band return loss requirements, option A

The device shall meet the return loss requirements specified in table 5. The $Z_{LOAD}$ values of table 5 are used in figures 19 and 20.

**Table 5: Return loss requirements, option A**

| Test # | Value of $Z_{LOAD}$ | Frequency range | Minimum Return Loss |
|--------|---------------------|-----------------|---------------------|
| Test 1 | $Z_{SL}$ | 300 Hz to 3,4 kHz | 12 dB |
| Test 2 | $Z_{SL}$ | 3,4 kHz to 4 kHz | 8 dB |
| Test 3 | $Z_R$ | 300 Hz to 3,4 kHz | 12 dB |
| Test 4 | $Z_R$ | 3,4 kHz to 4kHz | 8 dB |
| NOTE 1:   A value of 14 dB for the minimum Return Loss instead of 12 dB is desirable. | | | |
| NOTE 2:   $Z_R$ and $Z_{SL}$ are defined in clause 5.2.2, in figures 5 and 6 respectively. | | | |

### 6.6.2    POTS pass band return loss requirements, option B

For the case of option B, $Z_{LOAD}$ in figures 19 and 20 shall be $Z_R$. The device shall meet the return loss requirements specified in figure 26.
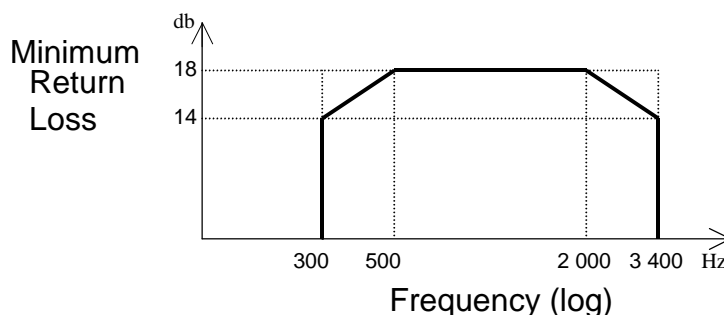


**Figure 26: Minimum return loss template for option B**

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

In case pulse metering signals are deployed on the same lines as xDSL, the insertion loss due to the splitter ($IL_{Meter}$) shall be measured at the frequency of the metering pulse. The test needs to be done in one direction only. 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.

Splitters at the LE side of the line shall be tested from POTS port to LINE port according to figure 14; splitters at the TE side of the line shall be tested from LINE port to POTS port according to figure 13. The conditions of table 6 shall be used.

The level of the test signal is 3,5 $V_{RMS}$ e.m.f. This requirement shall be met only for the off-hook condition, with the DC current as specified in clause 5.1.2. This requirement shall be met with the switch $S_{DSL}$ in figures 13 and 14 both open and closed.

**Table 6: Conditions for insertion loss test at 12 kHz or 16 kHz**

| Level of source voltage | Source Impedance (figures 13 and 14) | Load Impedance (figures 13 and 14) | Impedance at the xDSL port |
|---|---|---|---|
| 3,5 $V_{RMS}$ e.m.f. | $Z_{Meter}$, clause 5.2.8 (200 Ω) | $Z_{Meter}$, clause 5.2.8 (200 Ω) | $Z_{DSL}$ |

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

## 6.8 Unbalance about Earth

### 6.8.1 Unbalance of the low pass part

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 21 to 24. The test shall be carried out for the conditions described in table 7 and with switch S1 closed for measurements in the voice band. This requirement is applicable for both the on-hook and the off-hook condition of the TE. The DC feeding is as specified in clause 5.1.2.

**Table 7: Unbalance about earth, LCL and LCTL test set-ups**

| Test set-up # | Source port to termination port | Measurement port | Frequency range |
|---|---|---|---|
| **1**: LCL figure 21 | POTS (to LINE) | POTS | 50 Hz to 1,1 MHz |
| **2**: LCL figure 22 | LINE (to POTS) | LINE | 50 Hz to $f_{Max}$ (see note) |
| **3**: LCTL figure 21 | 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 values are given in table A.1.

For each of the test set-ups described above, the splitter shall meet the unbalance about earth requirements specified in table 8. The value of $f_L$, $f_H$ and $f_{Max}$ in table 8 is dependent on the xDSL variant involved. Specific values are given in tables A.4, A.5 and A.6.

**Table 8: Unbalance about earth, minimum values**

| Frequency range | State of S1 | Value of R | Minimum Unbalance value |
|---|---|---|---|
| 50 Hz to 600 Hz | Closed | 300 Ω | 40 dB LCL |
| 600 Hz to 3,4 kHz | Closed | 300 Ω | 46 dB LCL |
| 3,4 kHz to 4 kHz | Closed | 300 Ω | 40 dB LCL |
| 4 kHz to $f_L$ | Open | $Z_{RefDSL}/2$ | 40 dB LCL |
| $f_L$ to $f_H$ | Open | $Z_{RefDSL}/2$ | See annex A |
| $f_H$ to $f_{Max}$ | Open | $Z_{RefDSL}/2$ | See annex A |

Values of the unbalance in the xDSL band and above it are specified in the tables A.7 to A.10 in Annex A.3 to A.6 for each xDSL variant.

## 6.8.2    Unbalance of the high pass part for alternative B or C

This clause is limited to alternatives B and C of the high pass (see clause 5.3). For alternative A, when the high pass is absent, the balance at the LINE port is assessed with the balance measurement of the low pass in clause 6.8.1.

NOTE:       It should be clear that the common mode model of the source or the termination in the unbalance test set-up is not intended for modelling a xDSL transceiver in a realistic way. The common mode impedance is much too low at the lower edge of the xDSL pass band. As a result, for alternative B, the measurement in this clause is mainly an assessment of the mismatch between the two blocking capacitors.

The basic test set-up for measuring unbalance at the xDSL port is shown in figure 23. In the case of measuring at the LINE port, the test set-up of figure 24 is used. The test shall be carried out for the combinations described in table 9. It should be noted that the source and measurement points are always at the same port.

**Table 9: Unbalance about earth, test set-ups**

| Test set-up # | Source port to termination port | Measurement port | Frequency range |
|---|---|---|---|
| **4**: LCL figure 23 | xDSL (to LINE) | xDSL | $f_L$ to $f_{Max}$ (see note) |
| **5**: LCL figure 24 | LINE (to xDSL) | LINE | $f_L$ to $f_{Max}$ (see note) |
| NOTE:     $f_{Max}$ is still F.F.S for some xDSL cases; in those cases the frequency range is $f_L$ to $f_H$. | | | |

The POTS port shall be terminated by a 600 Ω resistor for all unbalance tests described in the present clause.

For each of the test set-ups described above, the splitter shall meet the unbalance about earth requirements as specified in table 10.

In the case of performing measurements at frequencies above 4 kHz, for reasons of practical testing a 150 Ω impedance should be used in series with the longitudinal source (i.e. S1 in figures 23 and 24 should be open).

**Table 10: Unbalance about earth, minimum values**

| Frequency range | State of S1 | Value of R | Minimum Unbalance value |
|---|---|---|---|
| $f_L$ to $f_H$ | open | $Z_{RefDSL}/2$ | See annex A |
| $f_H$ to $f_{Max}$ | open | $Z_{RefDSL}/2$ | See annex A |

## 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 splitter, 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 requirements of IL need to be measured in one direction only.

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

The minimum values of the isolation in the xDSL band in the on-hook condition are measured as an insertion loss ($IL_{DBOnH}$) between POTS port and LINE port. The respective values and frequency ranges are specified in tables A.2, and A.4 to A.6 for each specific xDSL variant. The on-hook DC feeding conditions are specified in clause 5.1.2.

NOTE 1: It is recognized that the values in this clause are sufficient to provide a suitable protection of the POTS service against the xDSL signals. Higher values may be required to provide an adequate protection of the xDSL service against POTS transients. This last issue is F.F.S., but WT-127 (see annex H) is considered an adequate way of evaluating how POTS transients affect xDSL. The whole WT-127 based methodology is still F.F.S.

NOTE 2: In previous versions of the present document this set-up contained a transmission measurement which was not an insertion loss. This was out-of-line with the other tests and therefore it was changed to a regular IL; also we measure now from POTS port to LINE port and no longer from xDSL port to POTS port. Only in part 2 (splitters over ISDN or universal splitters) an IL measurement between xDSL port and POTS port is still used.

The test needs to be done in one direction only. The test set-ups to be used are given in figures 13 **or** 14, i.e. to be measured from the LINE port to the POTS port, **or** in the opposite direction. The switch $S_{DSL}$ is always closed, because this type of isolation is only needed when an xDSL transceiver is present.

The impedance values are specified in table 11. The level of the test signal is -6 dBV e.m.f.

**Table 11: Impedances applied for on-hook isolation**

| Test Direction | LE side splitter | | | TE side splitter | | |
|---|---|---|---|---|---|---|
| | LINE port Impedance | POTS port Impedance | xDSL Port Impedance | LINE port Impedance | POTS port Impedance | xDSL Port Impedance |
| **LINE to POTS** | $Z_{RHF}$ | $Z_{RHF}$ | $Z_{DSL}$ | $Z_{RHF}$ | $Z_{OnHI}$ | $Z_{DSL}$ |
| **POTS to LINE** | $Z_{RHF}$ | $Z_{RHF}$ | $Z_{DSL}$ | $Z_{RHF}$ | $Z_{RHF}$ | $Z_{DSL}$ |

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

The minimum values of the isolation in the xDSL band in the off-hook condition are measured as an insertion loss ($IL_{DBOffH}$) between POTS port and LINE port. The frequency ranges are specified in tables A.4 to A.6 for each specific xDSL variant. The off-hook DC feeding conditions are specified in clause 5.1.2.

Splitters with the option A return loss requirement (see clause 6.6.1) shall fulfil the type A off-hook insertion loss requirement in table A.3.

Splitters with the option B return loss requirement (see clause 6.6.2) shall fulfil the type B off-hook insertion loss requirement in table A.3.

The test needs to be done in one direction only. The test set-ups to be used are given in figures 13 **or** 14, i.e. to be measured from the LINE port to POTS port, **or** in the opposite direction. The switch $S_{DSL}$ is always closed, because this type of isolation is only needed when an xDSL transceiver is present.

The impedance values are specified in table 12. The level of the test signal is -6 dBV e.m.f.

**Table 12: Impedances applied for off-hook isolation**

| Test Direction | LE side splitter | | | TE side splitter | | |
|---|---|---|---|---|---|---|
| | LINE port Impedance | POTS port Impedance | xDSL Port Impedance | LINE port Impedance | POTS port Impedance | xDSL Port Impedance |
| Line to POTS **or** POTS to Line | $Z_{RHF}$ | $Z_{RHF}$ | $Z_{DSL}$ | $Z_{RHF}$ | $Z_{RHF}$ | $Z_{DSL}$ |

NOTE:    As a compromise, it was decided to use $Z_{RHF}$ to model the impedance at the POTS port at both the TE and the LE sides. It was also decided not to measure any longer the IL between xDSL port and POTS port and POTS port to xDSL port. It is also known that for passive splitters, the IL needs to be measured in one direction only.

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

The minimum value of the signal loss in the transition band between 20 kHz and 32 kHz is measured as an insertion loss ($IL_{TBOffH}$) between POTS port and LINE port. It is measured only in the off-hook condition. The test needs to be done in one direction only. The measurement method and the source and load impedances are identical to clause 6.9.2. The DC feeding conditions are given in clause 5.1.2.

The optional requirements related to this clause are a template, which is a straight line marking the upper limit of the IL, connecting 0 dB at 20 kHz with 40 dB at 32 kHz. The frequency axis is logarithmic and the vertical axis is in dB.

NOTE 1:    The isolation in the transition band between 20 kHz and 32 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 TX PSD of these devices is within the allowed template, the actual xDSL residue signal leaking through the splitter, causes a relatively high signal around 25 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.

NOTE 2:    There will be a trade off between the isolation in this band and e.g. passing the metering signals at 12 kHz or 16 kHz. Similarly widening the POTS pass band of the low pass, to achieve option B, results in less attenuation in the transition band (and also in the stop band above 32 kHz, as described in clauses 6.9.1 and 6.9.2). Achieving at the same time a small attenuation of the metering and a good rejection in the transition band might require extra complexity, or it might not even be achievable. Similarly extra requirements such as an option B RL on multiple impedances could be incompatible with a good rejection in the transition band.

## 6.9.4    xDSL signal loss: IL LINE port to xDSL port

The test needs to be done in one direction only. The insertion loss $Att_{DB}$ due to the insertion of the low pass part of the splitter (i.e. **not including the blocking capacitors** in the case of high pass alternative B) from the LINE port to the xDSL port **or** in the opposite direction shall be tested according to clause 5.4.4, figure 16 **or** 18. The reference high pass is defined in clause 5.3.3. The impedance at the LINE side is $Z_{RHF}$. At the xDSL port the impedance is $Z_{DSL}$. The requirements are specified for different high pass alternatives in the clauses below.

NOTE:    For alternative A of the high pass the reference high pass is a short circuit in figures 16 and 18. Then figure 16 is converted into figure 17. A similar simplification can be derived for figure 18.

The insertion loss requirements are to be met in the case where $Z_{POTS}$ of figure 16 or 18 is a short circuit, an open circuit, and the nominal $Z_{RHF}$ impedance of clause 5.2.3. The DC feeding is as specified in clause 5.1.2.

### 6.9.4.1    High pass alternatives A and B

For a high pass alternative A or B (see clauses 4.2 and 5.3.1) the insertion loss requirements of table 13 are to be met.

**Table 13: Insertion loss between LINE port and xDSL port for xDSL over POTS splitters**

| 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 contains no test to cover this transitional effect. However, WT-127 will address this issue. See annex H on WT-127. The whole WT-127 based methodology is still F.F.S.

### 6.9.4.2       High pass alternative C

For a high pass alternative C (see clauses 4.2 and 5.3.2) The insertion loss requirements of table 14 are F.F.S.

**Table 14: Insertion loss between LINE and xDSL port for xDSL/POTS splitters**

| Frequency range | Insertion loss between LINE and xDSL port |
|---|---|
| $f_L$ to TBD kHz | ($Att_{DB}$ is F.F.S.) |
| TBD kHz to $f_H$ | ($Att_{DB}$ is F.F.S.) |

NOTE:     Rather than studying the $Att_{DB}$ of the high pass filter alternative C, and fixing an absolute requirement, the quality of the HPF can be tested with the WT-127 methodology. When comparing a baseline splitter with a normal set of blocking capacitors with the splitter DUT with the higher order HPF, a maximal loss of margin or of bitrate could be specified. The whole WT-127 based methodology is still F.F.S.

## 6.10      Noise levels

Noise measurements need only to be specified for active/dynamic splitters. They are F.F.S. and they are introduced in annex K.

## 6.10.1    POTS band audible noise level

The psophometric noise power $N_{PB}$ is only measured for active/dynamic splitters, as discussed in annex K.

## 6.10.2    xDSL band noise level

Noise in the xDSL band $N_{DB}$ is only measured for active/dynamic splitters, as discussed in annex K.

## 6.11      Distortion

## 6.11.1    POTS band intermodulation distortion

The test set-up to measure POTS band intermodulation distortion ($IMD_{PB}$) is given in figure 13. This requirement shall be met with the switch $S_{DSL}$ in figure 13 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.

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.

The test signal to be used is specified in 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 the POTS port.

NOTE 2: A methodology for performing this test in the presence of a xDSL signal is available in [i.3] and [i.5]. It was thought that this represents a more realistic scenario for splitter evaluation. However, this is doubtful. The WT-127 based methodology present in the next clause 6.11.2 is probably a more reliable approach to the test of splitter distortion in the presence of xDSL signals, but this is still F.F.S.

## 6.11.2    Extended xDSL band intermodulation distortion (informative)

This requirement is still F.F.S. However, to measure xDSL band intermodulation distortion ($IMD_{DB}$) it is expected that the WT-127 methodology under development by the Broadband Forum will be adopted.

NOTE: As long as the methodology in the Broadband Forum is not finalized and as long as the methodology is not replicated with sufficient consistency of the results in different certified labs, the content of this clause should be considered for information only. When the Broadband Forum methodology is finalized and replicated with sufficient consistency in independent test labs, ETSI will reconsider this clause to make it mandatory.

It is necessary to test the effect of the non-linear behaviour of the splitter components, under variable DC voltages and currents, under the strongest POTS AC signals including POTS AC ringing and also under the strongest possible wideband xDSL signals.

This can be done by dynamic tests, in which a splitter as Device Under Tests (DUT) operates in conjunction with 2 baseline xDSL modems and a baseline splitter. This kind of tests is under development at the Broadband Forum. These tests are described in the informative annex H.

For testing the xDSL distortion of a splitter, the methodology developed by the Broadband Forum (WT-127) will likely be adopted and reference will be made to the appropriate Broadband Forum documents.

## 6.12    Group delay distortion

The increase of the group delay distortion resulting from the insertion of one splitter shall be measured in the frequency range 300 Hz to 4 kHz. The increase shall comply with the limits specified in table 15.

**Table 15: Group delay distortion, maximum values**

| Frequency range | Maximum value |
|---|---|
| 200 Hz to 600 Hz | 250 µs |
| 600 Hz to 3,2 kHz | 200 µs |
| 3,2 kHz to 4 kHz | 250 µs |

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 $\Omega$, 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 13. This requirement shall be met with the switch $S_{DSL}$ in figure 13 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    POTS transient effects (informative)

A POTS transient test existed in previous versions of the present document, 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 test method was removed completely.

Recently a new approach to transient testing was developed by in the Broadband Forum. The Broadband Forum document Working Text 127 (WT-127) describes this methodology, which consists in testing the splitters on a real line, with two baseline xDSL modems and with the injection of POTS LE signals (POTS AC, POTS DC, ringing, etc.) including POTS TE transients, such off-hook and ring-trip. The whole WT-127 based methodology is still F.F.S.

The methodology of the WT-127 test is introduced already in clause 6.11.2 and described in the informative annex H.

## 6.14     Requirements for Common Mode Rejection (optional)

In the present document the Common Mode Rejection Ratio (CMRR) requirement is limited to ADSL. A similar requirement for ADSL2plus and for VDSL, i.e. in the band above 1,1 MHz, is F.F.S.

The CMRR is measured from the POTS port to the LINE port and from POTS port to the xDSL port, according to the method of clause 5.7. This measurement is to be carried out with the off-hook DC feeding current conditions specified in clause 5.1.2.

The splitter shall have a Common Mode Rejection Ratio (CMRR) better than the boundaries shown in figure 27. In the set-up the following resistor values are used: $R1 = R2 = Z_{RefDSL}$, see annex A. E.g. $Z_{RefDSL} = 100\ \Omega$ for ADSL. The third port of the splitter device is left not terminated (i.e. open).
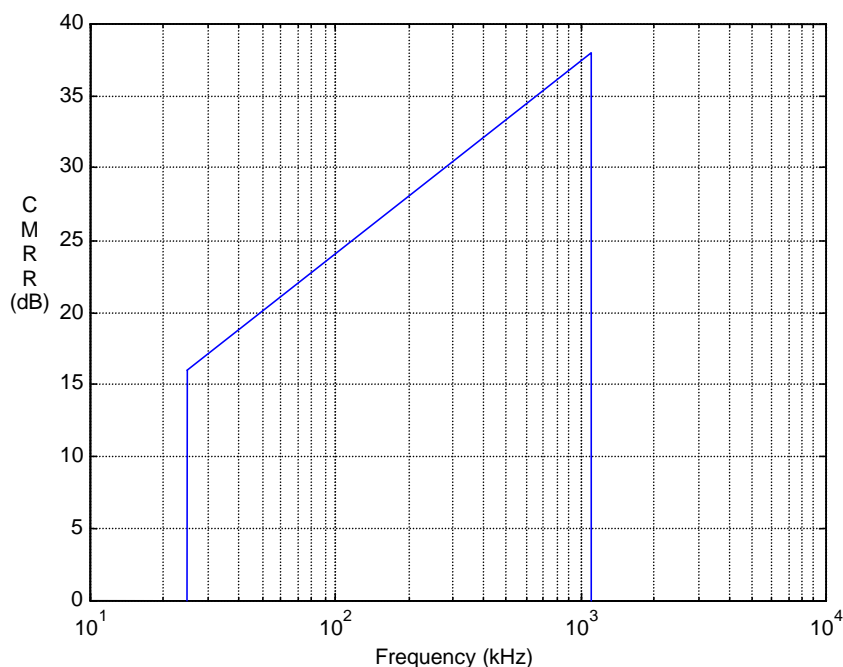


NOTE 1:   For frequencies up to 50 Hz the CMRR should preferably be low (< 6 dB). However this value is F.F.S.
NOTE 2:   The vertical edges of the mask in figure 27 are at 25 kHz and at 1,104 MHz.

**Figure 27: Mask of the minimum CMRR**

## 6.15     Requirements for Crosstalk at the LE (optional)

For a board with multiple splitters at the LE side of the line (at LE or cabinet) the splitter can be a source of additional crosstalk between lines, which is added to the crosstalk of the cables, the backplanes, other boards and other elements in the DSLAM. This section is F.F.S.

One general way of define the requirement would be to ask that the crosstalk should be better than the crosstalk in the cable for some typical or minimal length of cable. The type of cable to make this comparison has to be defined.

# Annex A (normative):
# xDSL specific information

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

In many of the tests, the xDSL port of the splitter 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 $C_{DCB}$, $Z_{RefDSL}$, $C_{DSL}$ and $L_{DSL}$

$Z_{DSL}$ is an impedance, connected as a termination at the xDSL port of the splitter. 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.
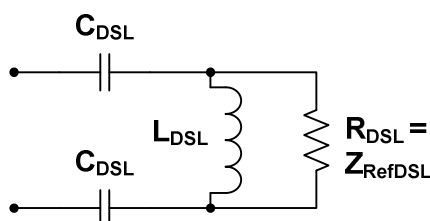


**Figure A.1: Equivalent schematic of the $Z_{DSL}$ HPF impedance model**

There are two different $Z_{DSL}$ variants, depending on the presence or absence of the (optional) high pass filter inside the splitter (see figure 2). They differ only in the value of the DC blocking capacitor $C_{DSL}$ in the model of figure A.1.

- The first variant of $Z_{DSL}$ is intended for use with a splitter not containing a high pass section (alternative A of clause 5.3).

- The other variant of it is intended for use with a splitter containing a high pass section (alternatives B or C described in clauses 5.3.1 and 5.3.2).

$Z_{RefDSL}$ 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 $Z_{RefDSL}$ of the xDSL at that lower edge.

The $C_{DSL}$ depends also on the pass band of the xDSL, but has 2 possible values for 2 distinct cases, i.e. when splitter includes DC blocking capacitors ($C_{DCB}$) or not. If the two capacitors $C_{DCB}$ are present, the value of the $C_{DSL}$ will be larger to compensate the extra series impedance in the high pass part inside the splitter.

The impedance of the first variant of $Z_{DSL}$ is identical to the value of the series connection of the second variant of $Z_{DSL}$ and the high pass alternative B. In this way the total impedance of the xDSL transceiver model and the high pass as seen from the LINE port has always the same value.

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 $Z_{RefDSL} \equiv R_{DSL}$, 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 $R_{DSL}$ ($\equiv Z_{RefDSL}$). 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. |
| $C_{DCB}$ | 120 nF | 120 nF | 120 nF | not specified | 120 nF | F.F.S. |
| $C_{DSL}$ if $C_{DCB}$ is present | 100 nF | 100 nF | 60 nF | not specified | 100 nF | F.F.S. |
| $C_{DSL}$ if $C_{DCB}$ is absent | 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 ADSL over POTS, when the splitter does not contain DC blocking capacitors or a higher order series high pass filter, the impedance model of figure A.2 shall be used to terminate the xDSL port of the splitter.



**Figure A.2: Schematic diagram of the impedance $Z_{DSL}$ for ADSL over POTS, if blocking capacitors or a higher order series HPF are *absent* in the splitter filter**

In the case where either DC blocking capacitors or a higher order series high pass filter are present inside the splitter, the impedance network of figure A.3 shall be used to terminate the xDSL port of the splitter.
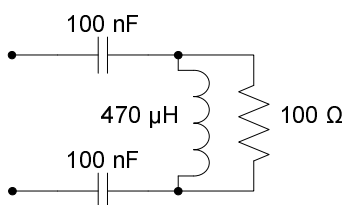


**Figure A.3: Schematic diagram of the impedance $Z_{DSL}$ for ADSL over POTS, if blocking capacitors or a higher order series HPF are *present* in the splitter filter**

# 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, when the splitter does not contain DC blocking capacitors or a higher order series high pass filter, the impedance model of figure A.4 shall be used to terminate the xDSL port of the splitter.
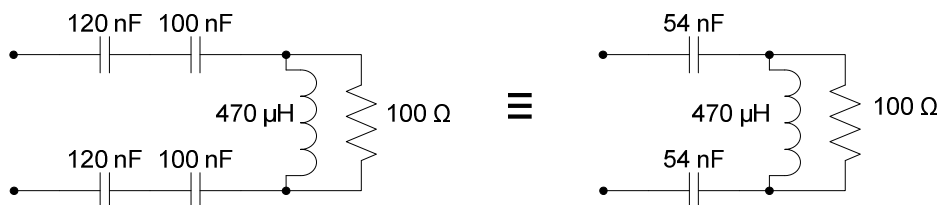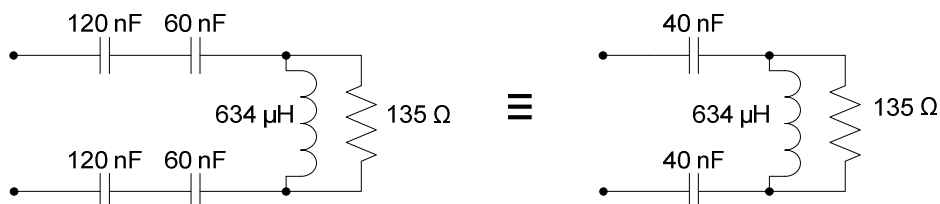


**Figure A.4: Schematic diagram of the impedance $Z_{DSL}$ for European VDSL1 over POTS, starting at 25 kHz if blocking capacitors or a higher order series HPF are *absent* in the splitter filter**

In the case where either DC blocking capacitors or a higher order series high pass filter is present inside the splitter, the impedance network of figure A.5 shall be used to terminate the xDSL port of the splitter.
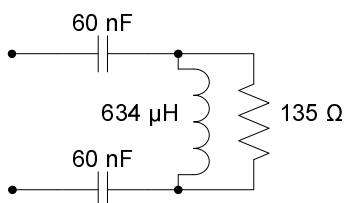


**Figure A.5: Schematic diagram of the impedance $Z_{DSL}$ for European VDSL1 over POTS, starting at 25 kHz if blocking capacitors or a higher order series HPF are *present* in the splitter filter**

# 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 POTS splitters

A complete overview of all common requirements for xDSL over POTS is listed in the following table. They apply to both LE and TE side splitters. Symbols are explained in clause 3.2. The specific frequency ranges for the individual xDSL types are compiled in additional tables A.4 to A.6.

**Table A.2: Dedicated requirements for splitters for xDSL system variants**

| Clause number | Symbol | Frequency Range | Splitters over POTS for xDSL |
|---|---|---|---|
| 6.2.1 | $R_{to\ Earth}$ | DC | > 20 M$\Omega$ |
| 6.2.2 | $R_{A\ to\ B\ wire}$ | DC | > 5 M$\Omega$ |
| 6.2.3 | $R_{DC}$ | DC | < 50 $\Omega$ |
| 6.3.1 | $V_{RD}$ | 25 Hz and/or 50 Hz | < 2 V (source e.m.f. 35 $V_{RMS}$) |
| 6.3.2 | $Z_{InRing}$ | 25 Hz and/or 50 Hz | > 40 k$\Omega$ / 36 k$\Omega$ |
| 6.3.3 | $THD_{Ring}$ | 25 Hz and/or 50 Hz | < 10 % |
| 6.4.1 | $IL_{PBOnH}$ | 200 Hz - 2,8 kHz | ± 4 dB |
| 6.4.2.1 | $IL_{PBOnH}$ | 1 kHz | ± 1 dB |
| 6.4.2.2 | IL-distortion | 200 Hz - 2,8 kHz | ± 1 dB relative to IL @ 1 kHz |
| 6.5.1 | $IL_{PBOffH}$ | 1 kHz | ± 1 dB |
| 6.5.2 | IL-distortion | 200 Hz - 4 kHz | ± 1 dB relative to IL @ 1 kHz |
| 6.6 | $RL_{PBOffH}$ | 300 Hz - 4 kHz **or** 300 Hz - 3,4 kHz | Option A in clause 6.6.1 **or** Option B in clause 6.6.2 |
| 6.7 | $IL_{Meter}$ | 12 kHz and 16 kHz | Optional (< 5 dB suggested) |
| 6.8.1 low pass | $UaE_{POTSband}$ | 50 Hz - 600 Hz<br>600 Hz - 3,4 kHz<br>3,4 kHz - 4 kHz | > 40 dB<br>> 46 dB<br>> 40 dB |
| 6.8.1 low pass | LCL LCTL | DSL band | Balance differs depending on the xDSL variant and differs between LE and TE side. See specific clauses A.3 to A.6 |
| 6.8.2 high pass | $LCL_{xDSLport}$ $LCL_{LINEport}$ | DSL band | |
| 6.9.1 | $IL_{DBOnH}$ | $f_L$ - $f_{M2}$<br>$f_{M2}$ - $f_H$ | > 34 dB<br>> 51 dB |
| 6.9.2 option A | $IL_{DBOffH}$ | DSL band | Might differ between LE and TE side. See table A.3 |
| 6.9.2 option B | $IL_{DBOffH}$ | DSL band | |
| 6.9.3 | $IL_{TBOffH}$ | 20 kHz - $f_L$ | Optional; only in off-hook |
| 6.9.4 | $Att_{DB}$ | $f_L$ - 50 kHz<br>50 kHz - $f_H$ | -0,5 dB < $Att_{DB}$ < 3 dB<br>-0,5 dB < $Att_{DB}$ < 1 dB |
| 6.10.1 | $N_{PB}$ | 200 Hz - 4 kHz | N.A. for passive splitters |
| 6.10.2 | $N_{DB}$ | $f_L$ - $f_H$ | N.A. for passive splitters |
| 6.11.1 | $IMD_{PB}$ | POTS band | See requirement in the clause |
| 6.11.2 | $IMD_{DB}$ | DSL band | F.F.S. using WT-127 of Broadband Forum |
| 6.12 | Group Delay | 200 Hz - 600 Hz<br>600 Hz - 3,2 kHz<br>3,2 kHz - 4 kHz | < 250 µs<br>< 200 µs<br>< 250 µs |
| 6.13 | Transients | POTS and xDSL | F.F.S. using WT-127 of Broadband Forum |
| 6.14 | CMRR | 25 kHz - 1,1 MHz | Optional, see clause; limited to ADSL1 |
| 6.15 | Crosstalk | DSL band $f_L$ - $f_H$ | See specific clauses A.3 to A.6 |

**Table A.3: Differentiation of IL in the xDSL band between LE and TE side**

| Clause number | Symbol | Frequency Range | Splitters over xDSL over POTS at the LE side | Splitters over xDSL over POTS at the TE side |
|---|---|---|---|---|
| 6.9.2 option A | $IL_{DBOffH}$ | $f_L - f_H$ | > 55 dB | > 55 dB (see note) |
| 6.9.2 option B | $IL_{DBOffH}$ | $f_L - f_{M1}$ | > 45 dB | > 45 dB (see note) |
| | | $f_{M1} - f_H$ | > 55 dB | > 55 dB (see note) |
| NOTE: | For FDD systems the upstream (US0 or US) at the TE side (transmitted) needs less protection. ADSL1, ADSL2 and ADSL2plus are usually deployed without overlap of US and DS, i.e. with FDD (Frequency Division Duplexing). (Similarly VDSL usually only uses FDD). At the TE side the US transmitter does not need the same protection as the US receiver at the LE side. Therefore, it is possible to relax the splitter isolation from POTS port to the LINE or xDSL port, in the US band. Furthermore, by reducing the IL in the range $f_L$ to $f_{M1}$, the IL above $f_{M1}$ could be increased. This would protect the downstream of a triple play data stream better, which could be proven with the WT-127 methodology. For example: <br> - Option A: at TE side (e.g.) 45 dB up to $f_{M1}$ and (e.g.) 65 dB above $f_{M1}$ up to (e.g.) 1,1 MHz could improve DS data protection for triple play. <br> - Option B: at TE side (e.g.) 40 dB up to $f_{M1}$ and (e.g.) 60 dB above $f_{M1}$ up to (e.g.) 1,1 MHz could improve DS data protection for triple play. <br> - With extra protection below (e.g.) 1,1 MHz for the DS, this might be reduced back to 55 dB above 1,1 MHz. <br> - The differentiation at the TE side is optional. The values are proposals. Exact values are F.F.S. | | | |

**Table A.4: Dedicated frequency ranges for splitters 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 |
| $f_{M2}$ | 350 kHz | 350 kHz |
| $f_H$ | 1 104 kHz | 2 208 Hz |
| $f_{Max}$ | 5 MHz | 5 MHz |

**Table A.5: Dedicated frequency ranges for splitters for VDSL1 system variants**

| Frequency Symbol | Splitters for VDSL1 over POTS ITU-T Recommendation G.993 [i.7] with US0 band (i.e. starting at 25 kHz) | Splitters VDSL 1 over POTS for ITU-T Recommendation G.993.1 [i.7] without US0 band or starting at 138 kHz or higher, |
|---|---|---|
| $f_L$ | 32 kHz | Lowest used VDSL1 freq. |
| $f_{M1}$ | 138 kHz | Highest of 138 kHz and lowest used VDSL1 freq. |
| $f_{M2}$ | 350 kHz | Highest of 350 kHz and lowest used VDSL1 freq. |
| $f_H$ | 12 MHz | 12 MHz |
| $f_{Max}$ | F.F.S. | F.F.S. |

**Table A.6: Dedicated frequency ranges for splitters for VDSL2 system variants**

| Frequency Symbol | Splitters for VDSL2 over POTS ITU-T Recommendation G.993.2 [i.8] with US0 band type A or M (starting at 25 kHz) | Splitters VDSL2 over POTS ITU-T Recommendation G.993.2 [i.8] without US0 band or starting at 138 kHz or higher |
|---|---|---|
| $f_L$ | 32 kHz | Lowest used VDSL2 freq. |
| $f_{M1}$ | 138 kHz | Highest of 138 kHz and lowest used VDSL2 freq. |
| $f_{M2}$ | 350 kHz | Highest of 350 kHz and lowest used VDSL2 freq. |
| $f_H$ | 30 MHz | 30 MHz |
| $f_{Max}$ | F.F.S. | F.F.S. |

# A.3 Specific requirements for passive splitters for ADSL over POTS variants

Specific requirements limited to passive splitters for ADSL over POTS are listed in the following table. They apply to both LE and TE side splitters. Symbols are explained in clause 3.2. Frequency values dedicated to ADSL are in table A.4.

**Table A.7: Dedicated requirements for passive splitters for ADSL over POTS variants at both the LE and the TE side**

| Clause number | Symbol | Frequency Range | Splitters over POTS for ADSL, ADSL2 or ADSL2plus |
|---|---|---|---|
| 6.8.1 low pass | $LCL_{POTSport}$ | 4 kHz - $f_L$ | > 40 dB |
| | | $f_L$ - 1,1 MHz | > 50 dB |
| 6.8.1 low pass | $LCTL_{POTStoLINE}$ or $LCL_{LINEport}$ | 4 kHz - $f_L$ | > 40 dB |
| | | $f_L$ - $f_H$ | > 50 dB |
| | | $f_H$ - $f_{Max}$ | > 30 dB |
| 6.8.2 high pass | $LCL_{xDSLport}$ or $LCL_{LINEport}$ | $f_L$ - $f_H$ | > 45 dB |
| | | $f_H$ - $f_{Max}$ | > 30 dB |
| 6.15 | Crosstalk | DSL band $f_L$ - $f_H$ | F.F.S. Only applicable at the LE side |

# A.4 Specific requirements for passive splitters for VDSL1 over POTS variants

Specific requirements limited to passive splitters for VDSL1 over POTS are listed in the following table. They apply to both LE and TE side splitters. Symbols are explained in clause 3.2. Frequency values dedicated to VDSL1 are in table A.5. 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.8: Dedicated requirements for passive splitters for VDSL1
over POTS variants at both the LE side and TE side**

| Clause number | Symbol | Frequency Range | Splitters for VDSL1 over POTS for any $f_L$ |
|---|---|---|---|
| 6.8.1 low pass | $LCL_{POTSport}$ | 4 kHz - $f_L$ | > 40 dB |
| | | $f_L$ - 1,1 MHz | > 50 dB |
| 6.8.1 low pass | $LCTL_{POTStoLINE}$ or $LCL_{LINEport}$ | 4 kHz - $f_L$ | > 40 dB |
| | | $f_L$ - $f_H$ | > 45 dB |
| | | $f_H$ - $f_{Max}$ | > 30 dB |
| 6.8.2 high pass | $LCL_{xDSLport}$ or $LCL_{LINEport}$ | $f_L$ - $f_H$ | > 45 dB |
| | | $f_H$ - $f_{Max}$ | > 30 dB |
| 6.15 | Crosstalk | DSL band $f_L$ - $f_H$ | F.F.S. Only applicable at the LE side |

# A.5 Specific requirements for passive splitters for VDSL2 over POTS variants at the TE side

Specific requirements limited to passive splitters for VDSL2 over POTS at the TE side are listed in the following table. Symbols are explained in clause 3.2. Frequency values dedicated to VDSL2 are in table A.6.

**Table A.9: Dedicated requirements for passive splitters for VDSL2
over POTS variants at the TE side**

| Clause number | Symbol | Frequency Range | Splitters for VDSL2 over POTS for any $f_L$ |
|---|---|---|---|
| 6.8.1 low pass | $LCL_{POTSport}$ | 4 kHz - $f_L$ | > 40 dB |
| | | $f_L$ - 1,1 MHz | > 50 dB |
| 6.8.1 low pass | $LCTL_{POTStoLINE}$ or $LCL_{LINEport}$ | 4 kHz - $f_L$ | > 40 dB |
| | | $f_L$ - 2,2 MHz | > 50 dB |
| | | 2,2 - 12 MHz | > 45 dB |
| | | 12 MHz - $f_H$ | Drop 20 dB/decade from 45 dB at 12 MHz |
| | | $f_H$ - $f_{Max}$ | > 30 dB |
| 6.8.2 high pass | $LCL_{xDSLport}$ or $LCL_{LINEport}$ | $f_L$ - 12 MHz | > 45 dB |
| | | 12 MHz - $f_H$ | Drop 20 dB/decade from 45 dB at 12 MHz |
| | | $f_H$ - $f_{Max}$ | > 30 dB |

## A.6 Specific requirements for passive splitters for VDSL2 over POTS variants at the LE side

Specific requirements limited to passive splitters for VDSL2 over POTS at the LE side are listed in the following table. Symbols are explained in clause 3.2. Frequency values dedicated to VDSL2 are in table A.6.

**Table A.10: Dedicated requirements for passive splitters for VDSL2
over POTS variants at the LE side**

| Clause number | Symbol | Frequency Range | Splitters for VDSL2 over POTS for any $f_L$ |
|---|---|---|---|
| 6.8.1 low pass | $LCL_{POTSport}$ | 4 kHz - $f_L$ | > 40 dB |
| | | $f_L$ - 1,1 MHz | > 50 dB |
| 6.8.1 low pass | $LCTL_{POTStoLINE}$ or $LCL_{LINEport}$ | 4 kHz - $f_L$ | > 40 dB |
| | | $f_L$ - 2,2 MHz | > 50 dB |
| | | 2,2 - 12 MHz | > 45 dB (see note) |
| | | 12 MHz - $f_H$ | Drop 20 dB/decade from 45 dB at 12 MHz (see note) |
| | | $f_H$ - $f_{Max}$ | > 30 dB |
| 6.8.2 high pass | $LCL_{xDSLport}$ or $LCL_{LINEport}$ | $f_L$ - 12 MHz | > 45 dB |
| | | 12 MHz - $f_H$ | Drop 20 dB/decade from 45 dB at 12 MHz |
| | | $f_H$ - $f_{Max}$ | > 30 dB |
| 6.15 | Crosstalk | DSL band $f_L$ - $f_H$ | F.F.S. |
| NOTE: The LCL requirements are based on what is reasonably achievable for an individual splitter at the LE side. However it is recognized that the requirements at the LE side and the TE side do not need to be identical. It is also recognized that it becomes increasingly difficult to meet the present document as the density of a board is increased. Therefore, further study is required to address the LCL and other issues relating to high density splitter boards. Regarding the LCL at the LE side it may be possible to relax the present document providing that due consideration is given to the effect on the entire system. Harmonization of the transceiver and splitter requirements should also be investigated. | | | |

# Annex B (informative):
# Evolution of the documents

This text explains the old organization of the splitter documents. It appears only in part 1 of the new documents. All other parts point to this informative annex.

In the past the drafts of the splitter specifications were under the responsibility of the working groups AT-A (recently renamed to AT1) and/or TM6, which were member of the technical committees AT and TM. Recently these group became member of a single technical committee called ATTM. Some documents were owned by AT1 (or AT-A in the past), others were owned by TM6. With the new simplified numbering, some documents now fall under both committees: the high pass part is under TM6 and the lowpass part under AT1.

In the previous version of the present document, Part 1 covered splitters for ADSL, while part 2 covered splitters for VDSL. The complete set of documents contained Part 1 with 5 subparts and Part 2 with 3 subparts as follows:

Part 1:    "(A)xDSL splitters for European deployment";

      Sub-part 1:    "Generic specification of the low pass part of xDSL over POTS splitters including dedicated annexes for specific xDSL variants" (to be replaced by the present document);

      Sub-part 2:    "Specification of the high pass part of ADSL/POTS splitters" (planned to be merged with sub-part 1 of part 1, or to be made generic for xDSL) (to be replaced by the present document);

      Sub-part 3:    "Generic specification of low pass and high pass part of xDSL over ISDN splitters and xDSL over ISDN or POTS universal splitters including dedicated annexes for specific xDSL variants";

      Sub-part 4:    "Specification for ADSL/"ISDN or POTS" universal splitters";

      Sub-part 5:    "Specification for ADSL/POTS distributed splitters";

Part 2:    "VDSL splitters for European deployment";

      Sub-part 1:    "Specification of the low pass part of VDSL/POTS splitters" (to be replaced by the present document);

      Sub-part 2:    "Specification of the high pass part of VDSL/POTS splitters" (to be replaced by the present document);

      Sub-part 3:    "Specification of VDSL/ISDN splitters".

The reason behind this multi-part format was to facilitate maintenance and future enhancements. However, to reduce the number of documents, we decided to merge all xDSL over POTS into TS 101 952-1 (the present document) and xDSL over ISDN and over ISDN-or-POTS variants into TS 101 952-2 [i.12]. All distributed filters will appear in TS 101 952-3 [i.13], which might include the active/dynamic distributed filters also. Potentially a TS 101 952-4 [i.14] might be written, e.g. when the active/dynamic distributed filters would not fit into TS 101 952-3 [i.13].

Clearly all subparts used in the older document structure will become historical, once the new parts are published.

# Annex C (informative):
# Use of the present document for splitters at the cabinet

To test **splitters at the remote cabinet** the use of present document in its previous versions was kept F.F.S.

This was due to the fact that the splitters at the cabinet are connected to the LE with lines, which represent an extra length, between the splitter and the characteristic impedance ($Z_R$ or 600 Ω) present at the LE. This extra length "X" is marked in functional diagram of figure 1 in clause 4.1.

However, the European $Z_R$ is chosen in such a way that it represent both the $Z_R$ of the telephone equipment, the impedance of a line terminated by $Z_R$, and the impedance of a long line terminated by 600 Ω. As the splitters are tested with the European $Z_R$, this test covers the impedance of line connected at the cabinet. Similarly for 600 Ω equipment, the $Z_{SL}$ impedance models a short loop terminated by 600 Ω.

When splitters are tested to achieve a RL according to option A, they might be connected to both 600 Ω and $Z_R$ equipment at the LE, and they are tested with both $Z_R$ and $Z_{SL}$, which sufficiently represent various impedances seen at the cabinet, at the POTS port of the splitter. If the splitter achieves a good RL on these two test impedances, it can be used safely at the cabinet position also.

When splitters are tested to achieve a RL according to option B, the $Z_R$ impedance is the only reference impedance used in the deployment, and $Z_R$ represents the impedance seen at the POTS port of the splitter at the LE side of the cabinet for any line length between the cabinet and the LE.

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

The IL in the POTS band is measured according to a diagram (see figures 13 and 14) in which $Z_{DSL}$ is not present in the reference case. The fact that $Z_{DSL}$ is only present when the IL of the splitter is measured causes additional signal losses introduced by the $Z_{DSL}$. This extra loss due to the $Z_{DSL}$ limits the additional IL loss caused by the low pass, because the requirements in the present document state that the combined IL caused by both low pass and $Z_{DSL}$ should be within the agreed boundaries.

A similar reasoning can be done for the RL. The RL is measured for the combination of the splitter low pass in the presence and absence of the splitter. 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 splitter can cause.

If the splitter low pass is a replaced by a short circuit, the IL and the RL are not caused by the filter, but only by the $Z_{DSL}$. The effect of $Z_{DSL}$ are as follows (IL is independent of the direction and RL is the same for any port).
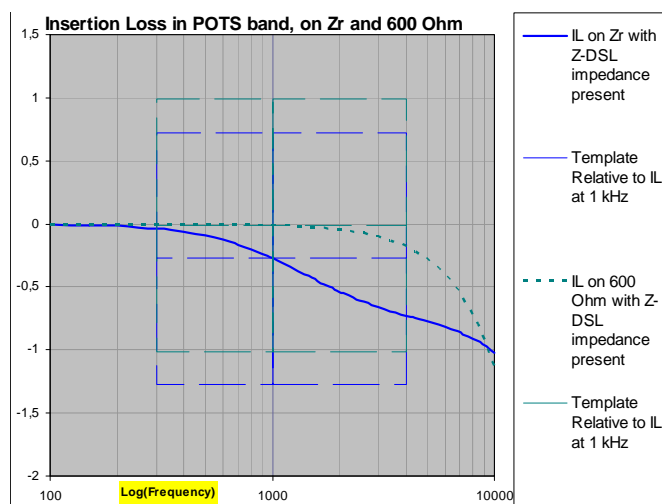


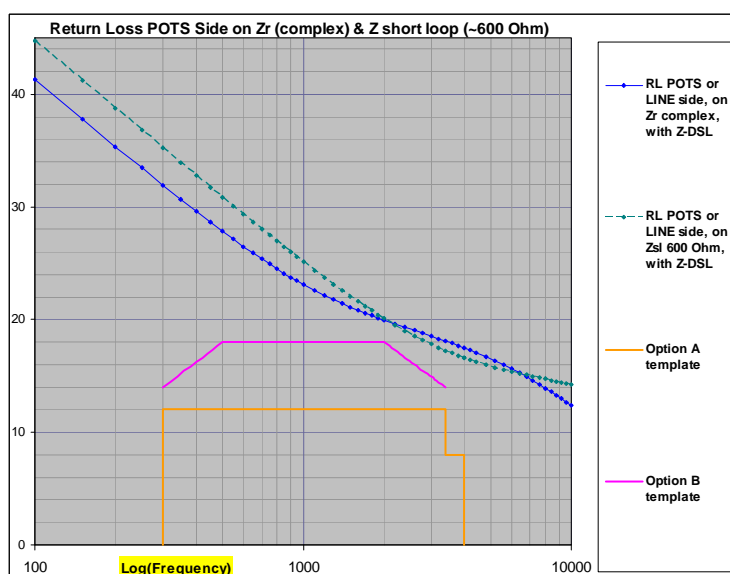**Figure D.1: IL effect of the $Z_{DSL}$ in the POTS band**



**Figure D.2: RL effect of the $Z_{DSL}$ in the POTS band at the POTS or the LINE port**

Note that the intrinsic RL degradation caused by the $Z_{DSL}$ is only 2 dB above the Option B template at 2 kHz.

# 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 documented in this informative annex.

NOTE:    These alternative schemes are presented here, because the documents [i.4] and [i.6] use these schemes to measure the IL from LINE port to xDSL port and reversed. This applies to clause 6.1 of [i.6] for the IL from LINE port to VDSL port and reversed. It also applies to the IL from LINE port to ADSL port (in clause 6.2 of [i.4]) and for IL from ADSL port to LINE port (in clause 6.1 of [i.4]). However in both [i.4] and [i.6] the reference case incorrectly contains no reference splitter high pass. Doing it the way of [i.4] and [i.6] will add extra losses if the splitter contains a first or higher order high pass filter. These extra losses are not relevant for the quality of the low pass, as already explained in note 1 of clause 5.4.4. These losses often prevent splitters to achieve this requirement, although the low pass part of the splitter is performing correctly.
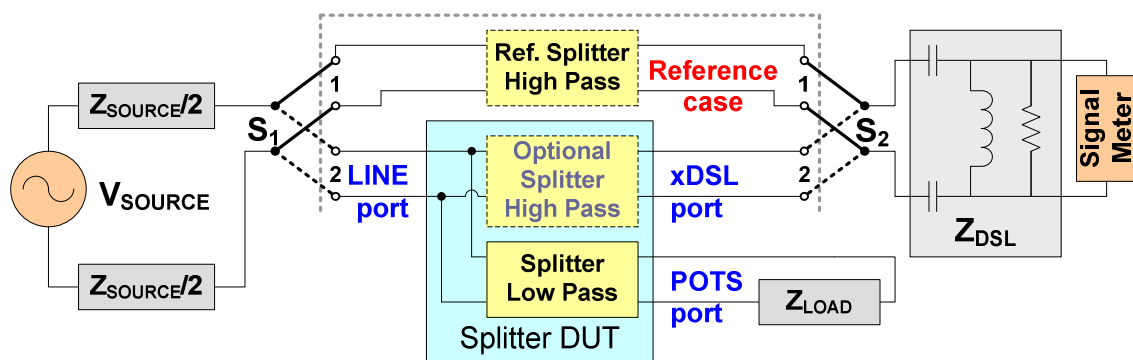


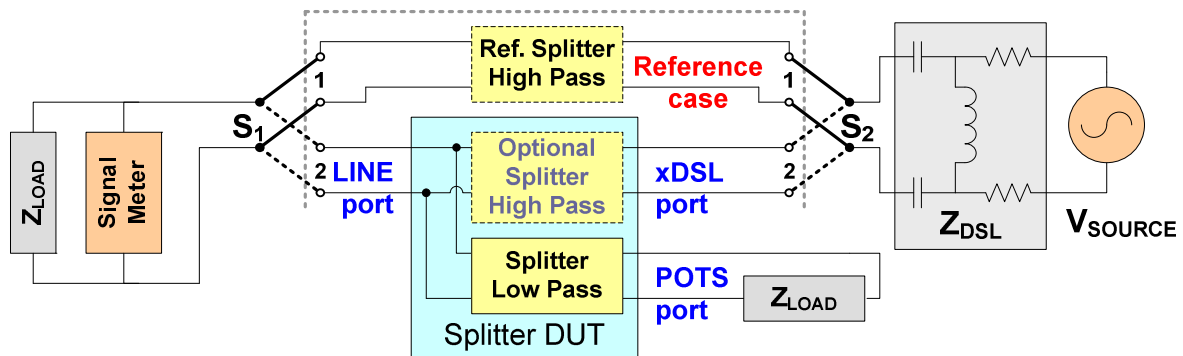**Figure E.1: Test set-up for Insertion Loss from POTS port to xDSL port, measured at $R_{DSL}$**



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

As shown in [i.4] and [i.6], the injection of signal from within the $Z_{DSL}$ or the measurement of the signal on the $Z_{RefDSL}$ (= $R_{DSL}$) can be done with circuits using a balun transformer inside $Z_{DSL}$. Consider the figures E.3, E.4, E.5 and E.6.

**Figure E.3: Sensing signal inside the $Z_{DSL}$ impedance with a 100:50 $\Omega$ BALUN**

**Figure E.4: Sourcing signal inside the $Z_{DSL}$ impedance with a 100:50 $\Omega$ BALUN**

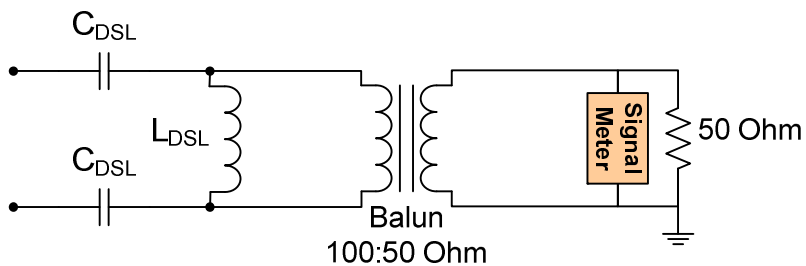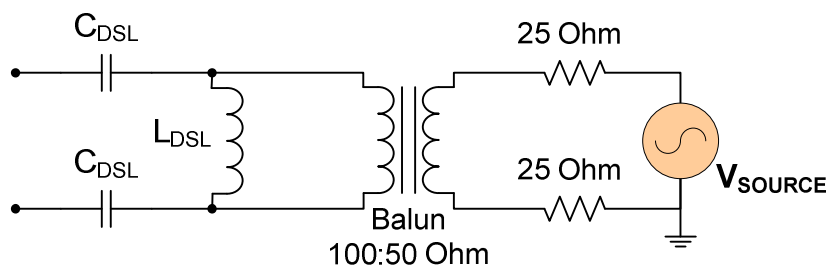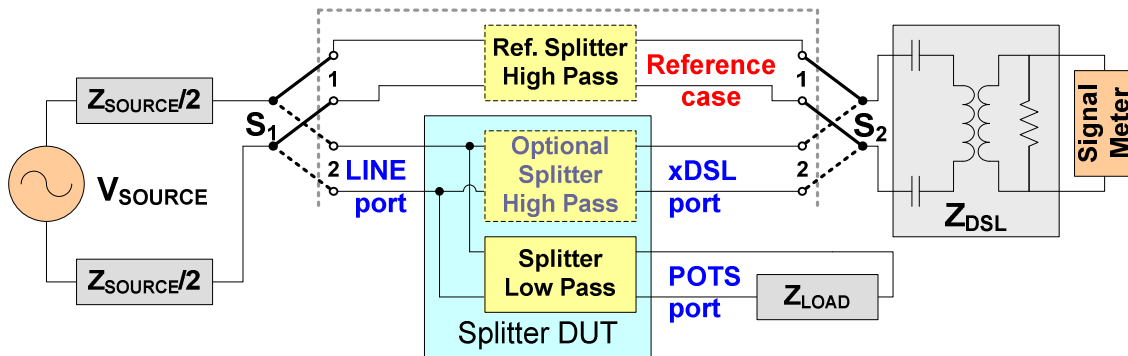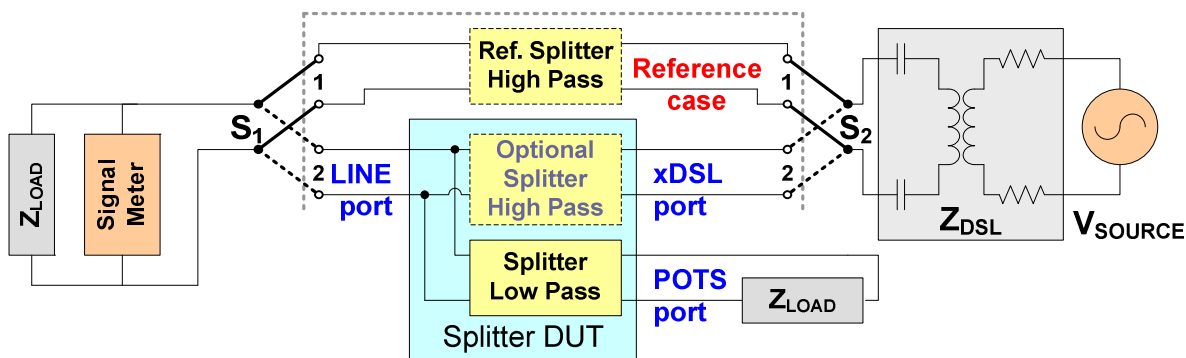**Figure E.5: Sensing signal inside the $Z_{DSL}$ impedance with a transformer**

**Figure E.6: Sourcing signal inside the $Z_{DSL}$ impedance with a transformer**

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

To measure the input impedance of a splitter terminated with a load impedance and to calculate the RL according to the formula of clause 5.4.6, the following practical diagrams show a bridge scheme with which the RL can be calculated by measuring voltages instead. It is possible to balance this scheme, but it is not absolutely necessary. The applicable formulae are shown inside the figures. $Z_{SOURCE}$ is $Z_{Ref}$ in the formula of clause 5.4.5. $Z_{Aux}$ is an auxiliary impedance.

For determining the RL of a splitter according to the formula defined in clause 5.4.6, $Z_{LOAD}$ is used as $Z_{SOURCE}$.
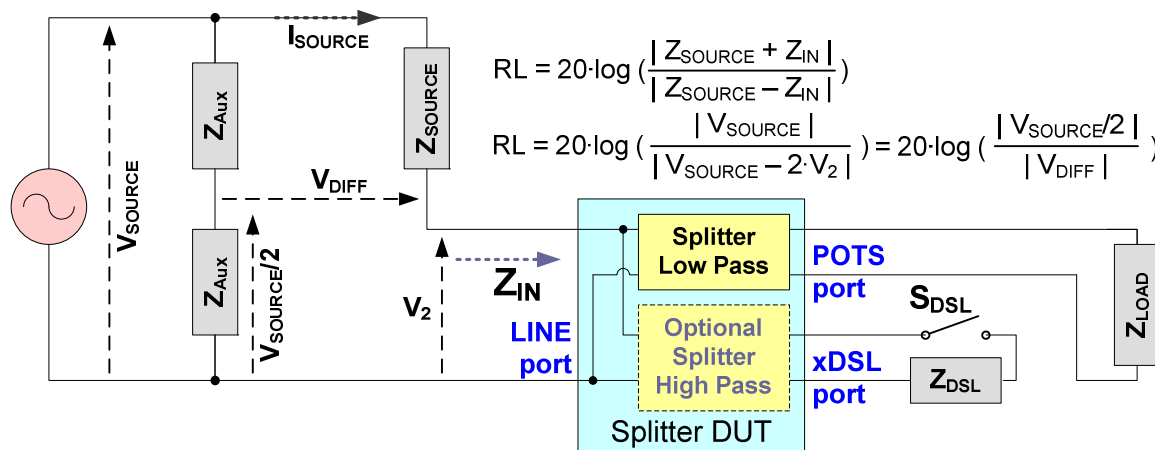


**Figure F.1: Practical test set-up for Return Loss at the LINE port**

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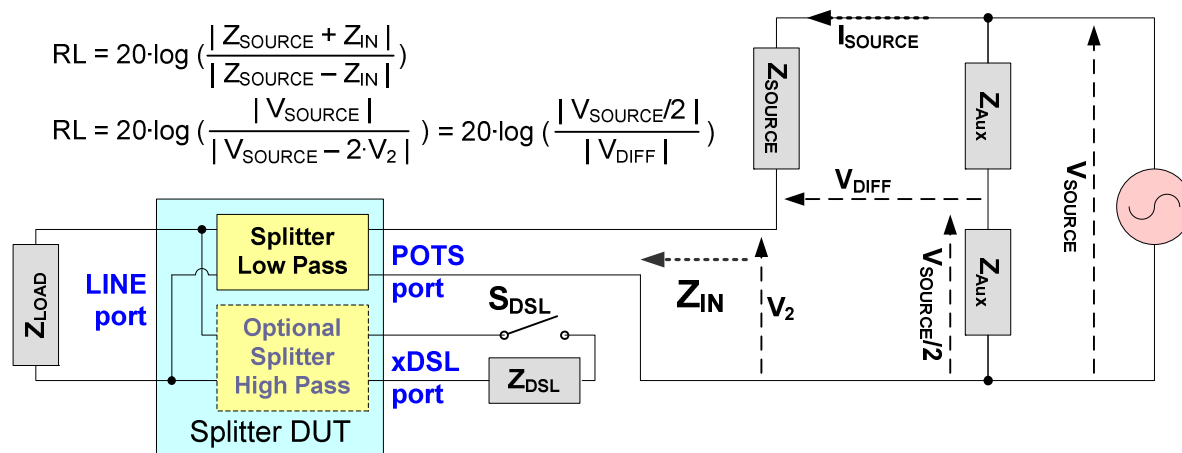


**Figure F.2: Practical test set-up for Return Loss at the POTS port**

The formulae inside the figures can be derived as follows:

$$RL = 20 \times \log\left(\frac{\left|Z_{SOURCE} + Z_{IN}\right|}{\left|Z_{SOURCE} - Z_{IN}\right|}\right) = 20 \times \log\left(\frac{\left|Z_{SOURCE} + Z_{IN}\right|}{\left|Z_{SOURCE} + Z_{IN} - 2 \times Z_{IN}\right|}\right) =$$

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

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

It is necessary to combine the measurements described in clauses 5.4 to 5.7 with the DC conditions of clause 5.1. This requires the combination of the circuits of the figures 13 to 25 with the feeding and loading bridges of clause 5.1.3. The next two figures show examples on how the figures 13 and 14 can be adapted to this combination. Similarly the other figures of clause 5.4 can be adapted to the DC feeding conditions. The diagrams are for information. Note that similar diagrams are available in the documents [i.3], [i.4], [i.5] and [i.6].

Figure G.1 shows the test set-up for Insertion Loss from the LINE port to the POTS port (as in figure 13) with the injection of DC feeding conditions of clause 5.1.2 via feeding and loading bridges of clause 5.1.3. This case is used for splitter at the TE side, where the DC voltage is sourced at the LINE port and the DC load is connected at the POTS port. For splitters at the LE side, the DC voltage source with the two $R_{FEED}/2$ resistors and the $R_{LOAD}$ should be interchanged in principle. Indeed, at the LE side the DC voltage enters the splitters via the POTS port and the load is connected via the LINE port.
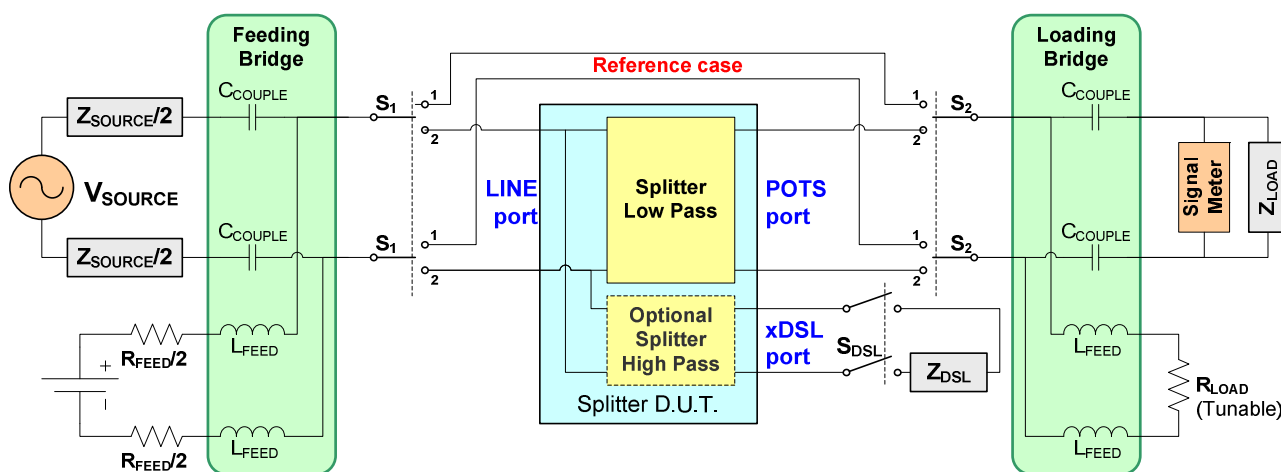


**Figure G.1: Test set-up for Insertion Loss from the LINE port to the POTS port, TE side splitters**

Figure G.2 shows the test set-up for Insertion Loss from the POTS port to the LINE port (as in figure 14) with the injection of DC feeding conditions of clause 5.1.2 via feeding and loading bridges of clause 5.1.3. This case is used for TE side splitter, where the DC voltage is sourced at the LINE port and the DC load is connected at the POTS port. As in figure G.1, for LE side splitters, the DC voltage source and the $R_{LOAD}$ should be interchanged.
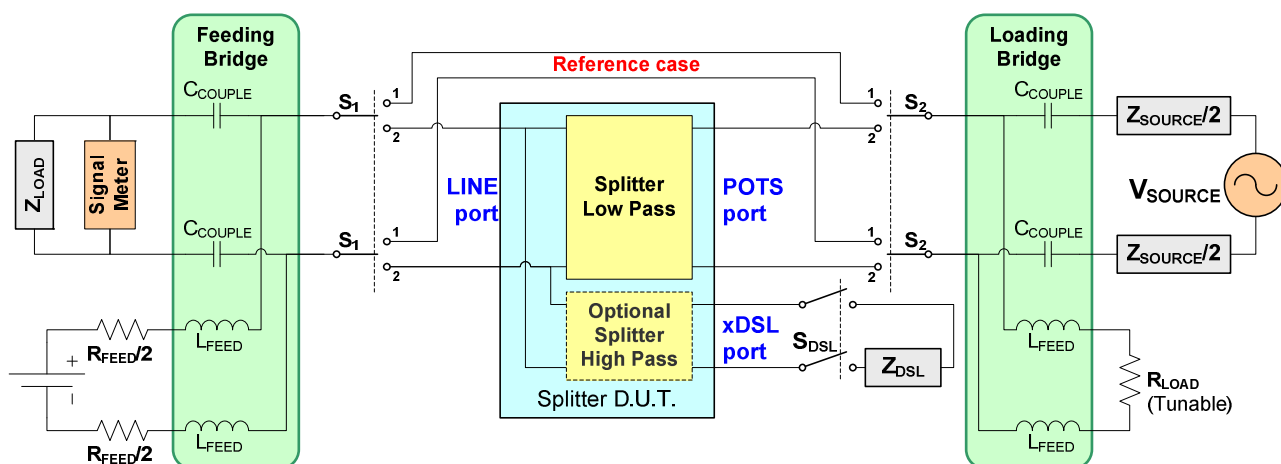


**Figure G.2: Test set-up for Insertion Loss from the POTS port to the LINE port, TE side splitters**

# Annex H (informative):
# Dynamic tests of splitters in the presence of xDSL transceivers (WT-127 of the Broadband Forum)

## H.1    General description

The Broadband Forum (previously the DSL forum) has been working on a dynamic test methodology for splitters. WT-127 is a system test, intended to give an indication about the quality of the splitters, but always as part of a complete system. The test delivers results for a system with 2 baseline modems and 1 baseline splitter and 1 splitter under test, two noise generators, and a transmission line.

The WT-127 methodology allows checking several things:

1) In static tests under continuous signals with various DC current values, or AC continuous ringing, the margin and the bitrate of the xDSL should be compared to a reference case, in which no splitters or only baseline splitters are present. Compared to the reference case and compared to baseline splitter devices the margin and bitrate should not drop significantly. If POTS splitters affect the xDSL transmission, this is due to several causes:

   - Linear signal losses, such as the $ATT_{DB}$ between LINE port and xDSL port in the xDSL band.

   - Non-linear effects linked to harmonic or intermodulation distortion of the xDSL US and DS signals, or between xDSL signals and POTS signals, such as DC current and AC ringing.

   - Noises generated in (most-likely active) components or circuits inside the splitters.

2) In test with POTS transients, it is checked if the splitter can mask POTS transients sufficiently. In an optimal situation, the xDSL will not suffer any additional CRC errors during transients, compared to its operation under stable DC or AC ringing POTS conditions. These tests show how splitters are capable of masking the POTS transients (both voltage and impedance changes and associated current variations). The transients used are representing most typical injections of non-stationary signals:

   - On-hook to off-hook transitions and back.

   - Cadenced ringing, injected in an xDSL unfriendly way.

   - Ring-trip, i.e. off-hook during ringing.

   - Note that metering and DC signalling are not yet part of the WT-127 methodology.

3) One additional way of using the WT-127 methodology is to prove that the interoperation of POTS and xDSL transmission is sufficiently good. This allows comparing splitters, which not necessarily track the static requirements of the present document. Three examples:

EXAMPLE 1:    The static properties of a splitter might be relaxed below the normal static requirements. Then the performance of such a splitter can be tested with WT-127 methodology. This might prove that the existing static requirements are unnecessarily strong and clearly not needed.

        E.g. the isolation of a splitter (measured as insertion loss) in the xDSL band is measured according to the static requirements in the present document. However, if a splitter is proposed with a relaxed $IL_{DB}$, it is possible with the WT-127 methodology to prove that the xDSL service is sufficiently well protected in spite of this relaxed static IL requirement: a strong IL e.g. at the US edge might be unnecessary.

EXAMPLE 2:    The WT-127 methodology could even prove that some of the static splitter requirements are even insufficient to protect xDSL against certain POTS transients.

        E.g. it could be better to relax some of these requirements in some frequency bands and to strengthen them in other frequency ranges. E.g. extra IL in the DS band is beneficial, which could need to relax the IL in the US0/US band, to keep the complexity lower.

EXAMPLE 3:    Similarly the WT-127 methodology can check the use of active and/or dynamic circuits in splitters.

The WT-127 methodology can show that splitters with some active and/or dynamic circuits may protect the xDSL in a better way than splitters that are purely passive and static.

If the active and/or dynamic circuits reduce the overall complexity of a splitter, the WT-127 methodology may show that such a splitter is still protecting against e.g. POTS transients in a sufficiently good way compared to the splitters that are purely passive and static.
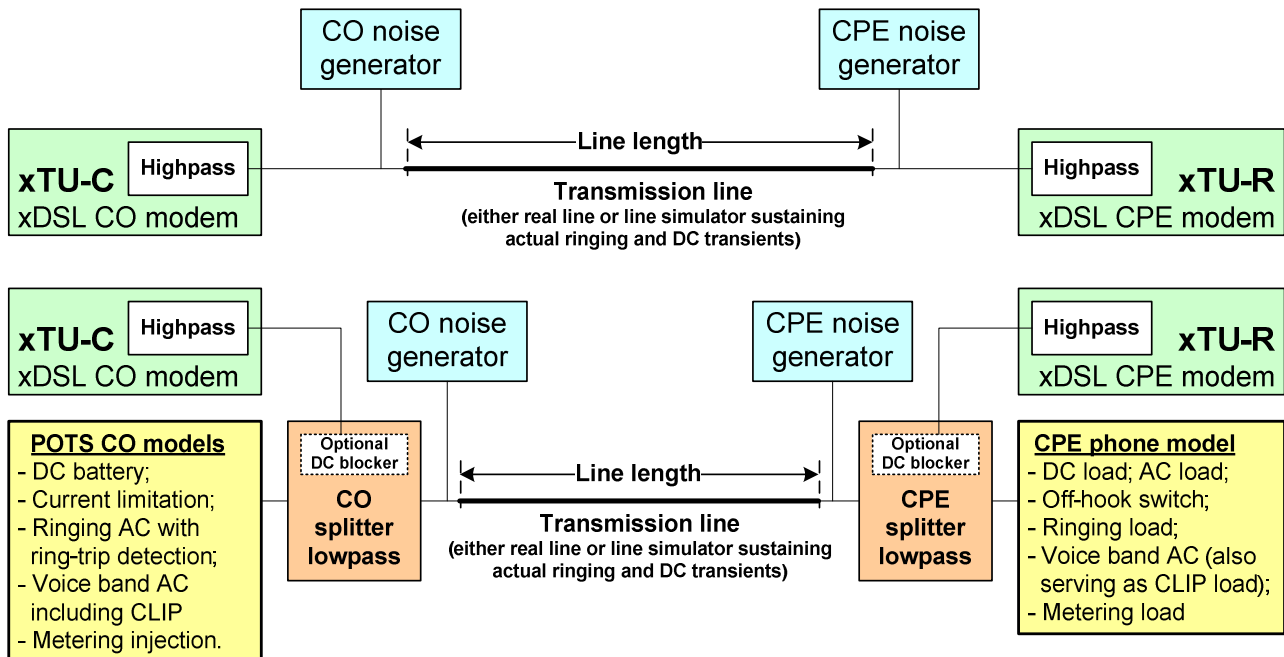


**Figure H.1: General test set of the WT-127 test methodology**

# H.2    Detailed description

The WT-127 (Working Text) contains a methodology, which is testing the splitters on a real line (or a line simulator with properties similar to a real line), with two xDSL modems and with the injection of AWGN noise and POTS signals (POTS AC, POTS DC, ringing, etc.) including POTS transients.

The general approach is to use a test set-up, in which two xDSL baseline modems are initialized in the presence of rather weak AWGN background noise, with and without two baseline splitters and POTS LE and TE models, with a fixed 6 dB margin. After establishing an xDSL link between the two xDSL baseline (i.e. reference) transceivers on a line (or line simulator), the bitrates are measured and the margin is checked with and without the splitters. Also the number of CRC errors is counted over a period of typically 2 minutes. $10^{-9}$ is considered an acceptable BER.

NOTE:    The baseline splitters are constructed or chosen such that the bitrate and the margin of the xDSL system do not differ substantially, with or without them.

This system is tested on different line lengths. For each line length the reference and the baseline system can train up to a certain bitrate, with a 6 dB margin, with a very low BER. The bitrate of the set-up is noted for different line lengths. The reference case is in the absence of splitters. The baseline system assumes the presence of the baseline splitters. For the actual splitter tests one of the baseline splitters is replaced by the splitter DUT, and a margin or bitrate degradation may be measured.

The tests are divided in two categories: 1) tests with continuous signals and 2) tests with transients.

## H.2.1    Static tests under continuous signals according to WT-127

For the static tests the splitters (a baseline pair or one baseline splitter and one DUT) are tested under:

- Continuous DC voltage and current cases (continuous on-hook or off-hook).

- Continuous Ringing with (multiple) on-hook phone loads.

- Note that metering injection is not yet part of the continuous injected signals.

The static tests allow checking the performance of the splitter by observing the xDSL signal degradation. The distortion requirement will then consist of an allowed degradation of the margin or of the bitrate for certain line lengths, when splitters are tested under the WT-127 methodology. The exact requirements are for still F.F.S. E.g. a maximal margin or bitrate reduction could be specified. The bitrate reduction could be specified in absolute or relative terms.

## H.2.2    Dynamic tests according to WT-127

Besides the "static" tests with continuous signals a number of dynamic tests are done with three types of POTS transients mentioned above in Annex H.1. The WT-127 methodology can be used in several ways. For testing the performance of splitter related to POTS transients, the different splitters can be ranked by counting the errors, or by imposing pass/fail criteria in certain cases.

- Different splitters can be ranked by counting the errors. A good splitter will demonstrate a very low error count in interleaved latency (which can be considered a virtual error free operation under the standardized POTS transients of the working text).

- In other cases pass/fail criteria can be imposed on splitters: they have to demonstrate virtual error free operation under POTS transients, which is defined as a very low error count in interleaved latency. Proposed pass/fail criteria require the xDSL to operate with a 6 dB noise margin, under which WT-127 allows 1 or less than one additional CRC error in the xDSL stream per 120 POTS transients. (Additional means that the CRC error count over two minutes in the absence of transients is used as the reference and that this amount of CRC errors should not be enhanced substantially by the splitters.)

- When dynamic tests are executed the xDSL should never lose synchronization. E.g. when the off-hook is tested the impedance of the POTS circuits modelled changes substantially. The xDSL should stay synchronized, with maximally a temporary increase of the CRC errors, to prove that impedance changes at the POTS port are masked sufficiently by the splitter low pass.

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

NOTE: This informative annex is mainly tutorial.

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

**General functional description of xDSL over POTS splitters (repeated from clause 4)**

The main purpose of the xDSL over POTS splitter is to separate the transmission of POTS signals and xDSL signals, enabling the simultaneous transmission of both services on the same twisted pair. The splitter also serves to protect POTS from interference due to egress from xDSL signals. Equally it protects the xDSL transmission from transients generated primarily during POTS signalling (dialling, ringing, ring trip, etc.), and it should 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 ADSL over POTS splitters is given in TR 101 728 [i.2]. Insertion of a splitter filter in existing POTS lines should only have a low impact on the performance of this service.

NOTE 1: An important statement is in note 1 of clause 5.4.1, which states that for passive splitters the IL between two ports is independent of the direction of the measurement. Of course, this allows to reduce the number of measurements by a factor of 2, but it also indicates that the separation between POTS and xDSL is independent of the direction. If the xDSL signal is attenuated by x dB at the POTS port, then the POTS signal is attenuated by the same amount at the xDSL port.

**Transmitting all xDSL and POTS signals with minimal disturbing influences**

Both xDSL and POTS signals should not be affected by noise, unbalance, harmonic distortion and intermodulation distortion.

**Transmitting POTS signals optimally**

To transmit the POTS signals optimally the DC, the ringing AC, the voice AC and the metering should not be affected by the splitters. Optimal transmission is possible with a minimal amount of losses introduced by the splitters and by the xDSL transceiver impedances. Besides loss of the POTS signals, another deterioration is caused by the enhancement of the echoes of the POTS voice band signals: this degrades the perceived quality of the audio signals, particularly for voice signals.

**Separating POTS and xDSL signals**

Noises of the POTS LE circuits (ringing with noisy 25 to 50 Hz AC generators, ring-relays, out-of-band aliasing of 4 kHz voice audio, etc.) and of the POTS phone circuits (pulse dialling, off/on-hook, ring trip, etc.) should be attenuated towards the LINE port and the xDSL port, which can be achieved above the POTS band. This isolation or attenuation is measured as an IL between the POTS port and the LINE port in the xDSL band $IL_{DB}$ and optionally in the transition band $IL_{TBOffH}$).

**Separating POTS and xDSL signals**

Furthermore, there is a need to prevent xDSL signals from reaching the POTS port. This means that isolation measurements should be performed both from the xDSL port (via LINE port) to the POTS port and from the remote xDSL terminal via the LINE port to POTS port. This isolation or attenuation is measured as an IL between the LINE port and the POTS port. As explained in note 2, measuring xDSL to POTS port or reversed is not needed as it adds no additional information.

NOTE 2: In a splitter without a series high pass filter, there is no difference between LINE port and xDSL port. In a splitter with the extra series capacitors, or even a higher order high pass filter, the attenuation between the POTS port and the xDSL port will be greater than the attenuation between the POTS port and the LINE port. For this reason these requirements only address the IL between the LINE port and the POTS port.

**Transmitting xDSL signals optimally**

Furthermore, there is a need to measure the loss of the xDSL signals ($Att_{DB}$) from the LINE port to the xDSL port or vice versa caused by the low pass section of the POTS splitter. This is measured as an IL between the xDSL port and the LINE port.

In relation to the $Att_{DB}$ (clause 6.9.4.1) the impedance changes at the POTS port can affect the xDSL signals. In the present document there is no requirement, describing how the IL between LINE port and xDSL port is allowed to change, when the impedance at the POTS port is changed, e.g. by going off-hook or by injecting ringing. In principle, a variation of the impedance at the POTS port will alter the amplitude and the phase of the xDSL signal at the LINE port and the xDSL port. These changes of the xDSL signal could (in theory) cause the xDSL transceivers to sustain errors or to fail. However, for splitters achieving an IL between POTS port and LINE port of more than 45 dB (option B) and 55 dB (option A) the input impedance of the splitter at the LINE port is normally sufficiently high at the lower edge of the xDSL band. Therefore, the effect of the changing POTS impedance at the POTS port seems effectively masked at the LINE port. Enforcing some absolute boundaries for the IL variation would be difficult, and it is simpler to cover this transitional requirement within clause 6.13. The WT-127 methodology will be most appropriate for this test, because it contains a transient test in which on-hook to off-hook transitions and other transients are applied at rapid pace.

**Relaxing the IL requirements at the TE/CPE side**

Refer to the note under table A.3.

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

It is recognized that a single set of feeding and loading bridges is not capable of covering the complete frequency range between the POTS band and $f_{MAX}$.

This is mainly due to the inductors, with high values for the POTS range, which have parasitic elements which compromise the test results at higher frequencies.

Therefore, it is recommended to split certain measurements over smaller frequency ranges, with dedicated feeding bridges with smaller inductors for the higher frequencies, typically above 1 MHz.

The balance of the feeding bridges is very important to avoid spurious results to be observed. Particularly for the measurement of LCL and LCTL the feeding of the DC current through the splitter should be controlled. However, it can be done, such that no coils are needed in the feeding circuit, and there are minimal unbalances introduced by the test set-up.

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

The present document is limited to passive and static splitters as stated in the introduction.

For active splitters additional tests are required and they are F.F.S. However, the following dedicated tests were already identified:

- Bidirectional IL tests might be needed.

- Noise tests (clauses 5.6 and 6.10).

- Distortion (clause 6.11).

- Transitional tests (clause 6.13).

# K.1     Bidirectional IL tests

The IL tests of passive splitters can be limited to a single direction, as stated in note 1 of clause 5.4.1. However, for active splitters this no longer applies. Therefore, all IL measurements for active splitters should be conducted in both directions. This applies to multiple subclauses in clause 6. The details are F.F.S.

# K.2     Noise measurements methods for active splitters

Noise requirements were unnecessary for passive splitters. This does not hold for active splitters. 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.2.1     (5.6.1) Psophometric noise in the POTS Band

The psophometric noise power, as defined in ITU-T Recommendation O.41 [4], is measured at the LINE port and the POTS port of a splitter. 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.2.2     (5.6.2) Noise in the xDSL Band

The noise in the xDSL band in active/dynamic splitters is measured indirectly with the WT-127 methodology, developed by the Broadband Forum. The methodology of the WT-127 test is introduced and described in the informative annex H. The WT-127 methodology allows to detect distortion and noises caused by a splitter device. This is done by measuring the xDSL rates in a few steps. First without splitters, then with baseline devices and finally with a baseline device and a splitter 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.3     (6.10) Noise requirements for active splitters

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.3.1 (6.10.1) POTS band audible noise level

The psophometric noise power NPB should be measured according to clause K.2.1 at the LINE port and the POTS port of a splitter, and should be less than -75 dBmp.

## K.3.2 (6.10.2) xDSL band noise level

For active splitters the xDSL band noise is tested, by observing an adequate xDSL operation with the methodology of the WT-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.4 (6.11) Distortion

This is F.F.S.

# K.5 (6.13) Transitional tests

This is F.F.S. Likely the WT-127 methodology, developed by the Broadband Forum will be used. The methodology of the WT-127 test is introduced and described in the informative annex H.

# Annex L (informative):
# Bibliography

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 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 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".

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

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.

WT-127 of the Broadband Forum: "Dynamic Testing of Splitters and In-Line filters with xDSL Transceivers".

   NOTE:   The straw ballot version of the WT-127 of the Broadband Forum is available as TD 32 in the meeting folder of meeting ATTMTM6 #52: http link. For users of the present document, who do not have access to the ETSI portal, WT-127 is described in annex H. As soon as the Broadband Forum has published their final version, it will be a publicly available Technical Report, expected to be listed as TR-127 at the Broadband Forum site: BB Forum Home link.

# History

| Document history | | |
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