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Access and Terminals (AT); Study for the specification of the low pass section of POTS/ADSL splitters

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access and Terminals (AT).

Introduction

The present document describes the basic information necessary to define requirements and test methods for POTS/ADSL splitters.

Technology developments, e.g. fast digital signal processors, facilitate the launch of applications like ADSL, corresponding to the ever increasing user demand for broadband services.

With ADSL technology, POTS and broadband data services are delivered to the user via a single copper pair. POTS uses the low frequency band, typically 0 kHz to 4 kHz, and data services use 26 kHz to 1 100 kHz. The signals are separated by a device called a "splitter". The present document covers aspects of the splitter that relate to the POTS services.

A more recent development, dealt with in the present document, is a so called distributed filter, which is a (small) low pass filter connected to each TE, instead of one common splitter for the whole user installation. **The intended application of the filters in the present document is for full rate ADSL** (the same application as with the common splitter).

Splitterless ADSL configuration according to ITU-T Recommendation G.992.2 [6], also designated "ADSL Lite", is outside the scope of the present document.

NOTE: Further experience and investigations may lead to some different results to be considered later.

1 Scope

The present document provides the basis for specification of requirements and test methods for the low pass section of POTS/ADSL splitters. These splitters are intended to be installed at the Local Exchange side of the local loop and at the user side near the NTP. The splitter at the user side may be part of the network or part of the user installation but will be always used to connect an access network using ADSL technology as described in ETR 328 [1] with a typical home installation.

The present document does not cover the possible advantages and disadvantages of the ownership of the splitter e.g. by the network operator, the user or a third party.

The present document covers most common situations to ensure a reasonable performance of this technology and facilitate the launch of such systems.

The high pass filter function of the splitter is not within the scope of the present document.

2 References

For the purposes of this Technical Report (TR) the following references apply:

[1] ETSI ETR 328: "Transmission and Multiplexing (TM); Asymmetric Digital Subscriber Line (ADSL); Requirements and performance".

[2] ETSI EG 201 120: "Public Switched Telephone Network (PSTN); Method of rating terminal equipment so that it can be connected in series and/or in parallel to a Network Termination Point (NTP)".

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

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

[5] ITU-T Recommendation O.132: "Quantizing distortion measuring equipment using a sinusoidal test signal".

[6] ITU-T Recommendation G.992.2: "Splitterless asymmetric digital subscriber line (ADSL) transceivers".

[7] ITU-T Recommendation G.992.1: "Asymmetric Digital Subscriber Line (ADSL) transceivers".

[8] ETSI EN 301 437: "Terminal Equipment (TE); Attachment requirements for pan-European approval for connection to the analogue Public Switched Telephone Networks (PSTNs) of TE supporting the voice telephony service in which network addressing, if provided, is by means of Dual Tone Multi Frequency (DTMF) signalling".

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

[10] ETSI TBR 38: "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".

[11] ETSI TBR 21: "Terminal Equipment (TE); Attachment requirements for pan-European approval for connection to the analogue Public Switched Telephone Networks (PSTNs) of TE (excluding TE supporting the voice telephony service) in which network addressing, if provided, is by means of Dual Tone Multi Frequency (DTMF) signalling".

3 Definitions and abbreviations

3.1 Definitions

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

non unbundled: access for terminal equipment to services provided by a PNO or PSP exclusively via the infrastructure of that PNO or PSP

unbundled: access for terminal equipment to services provided by a PNO or PSP via the infrastructure of another PNO or PSP

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

3.2 Abbreviations

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

AC	Alternating Current
ADSL	Asymmetric Digital Subscriber Line
CO	Central Office (Local Exchange)
DC	Direct Current
DSLAM	Digital Subscriber Line Access Multiplexer
EMC	Electro Magnetic Compatibility
HPF	High Pass Filter
ITU	International Telecommunication Union
LCL	Longitudinal Conversion Loss
LE	Local Exchange (Central Office)
LPF	Low Pass Filter
PAR	Peak-to-Average Ratio
POTS	Plain Old Telephone Service
TE	Terminal Equipment (e.g. Telephone, Fax, voice band modem etc.)
TTE	Telecommunications Terminal Equipment
xDSL	xDSL (generic) Digital Subscriber Line
PNO	Public Network Operator
PSP	Public Service Provider

4 General functional description of splitters

4.1 Overview

With some xDSL-systems (e.g. ADSL), POTS- and xDSL- signals may be transported simultaneously on the same copper wire pair in an access network.

To separate the signals, devices called splitters are used.

One splitter is placed in the LE, the other at the users premises (Remote splitter).

An overview is given in figure 1.

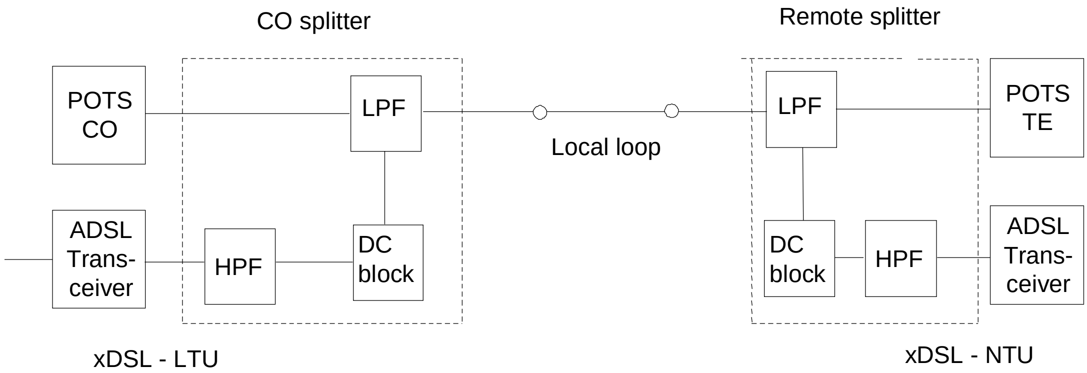


Figure 1: Overview of the use of splitters for separation of POTS and xDSL signals

The splitter function consists of a high pass filter (HPF), a low pass filter (LPF) and a DC blocking function (DC block). The three functional blocks of the splitter may be distributed, often combined with other network elements, for example the DC blocking function can be a separate function or can be a part the HPF or the LPF. It is quite common that the HPF is included in the ADSL transceiver.

Four different options for the splitter unit in the Local Exchange are shown in the four examples below. Example 1 is more suitable for the "non unbundled" situation while examples 2, 3 and 4 are for the"unbundled" situation:

1) LPF is in the splitter unit (HPF and DC-blocking function are in the ADSL modem);

2) LPF and DC-blocking function are in the splitter unit (the HPF is in the ADSL modem);

3) LPF, DC-blocking function and the full HPF are in the splitter unit;

4) LPF, DC-blocking function and a part of the HPF are in the splitter unit.

Advantages and disadvantages of the four options are discussed in clauses 4.2 to 4.5. Important points are:

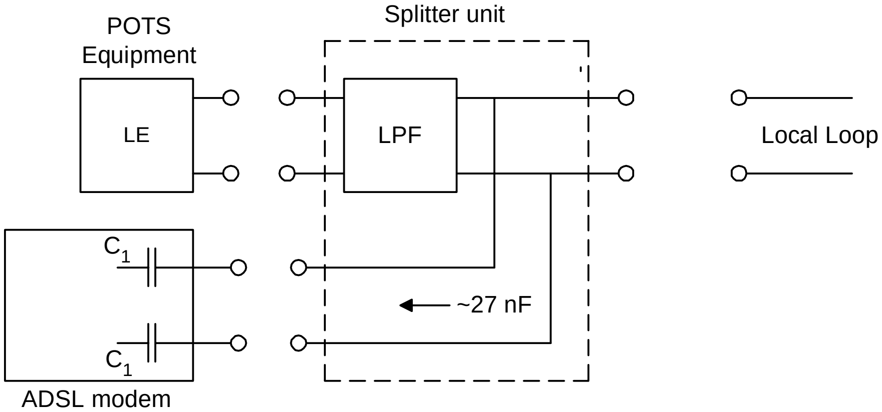
- quality control of the services;
- more separation of the services; and
- more clearly divided responsibilities in case of an "unbundled" loop.

At the users premises, example 1 is always used.

4.2 LPF in splitter unit (HPF and DC-block in ADSL modem)

This option (figure 2) is commonly used for the "non unbundled" loop. The same operator is responsible for the quality of both the POTS and ADSL services.

If this solution is used in an "unbundled" situation there is a risk of a bridged tap effect, possibly affecting the quality of the POTS service. This could happen if the splitter is at the POTS operator's exchange and there is a cable of some length to the DSLAM. The ADSL operator also has unnecessary access to the POTS service.



NOTE: The figure at the arrow (27 nF) is a rough indication of kind and the size of the impedance at low frequencies seen in the direction of the arrow.

Figure 2: Splitter unit without DC-blocking function

4.3 LPF and DC-bloc in splitter unit (HPF in ADSL modem)

This solution may be used in the "unbundled" situation. The ADSL operator has partial access to the POTS service (only to the AC signals, the DC is blocked).

The voice quality aspects of splitters may be controlled by the POTS or by the ADSL operator depending on the location of the splitter unit. Voice quality may not be the highest priority of the ADSL operator.

There is a risk for a bridged tap effect if the splitter is at the POTS operator's exchange and there is cable with some length to the ADSL operator's DSLAM. The DC-blocking function in the splitter unit limits this effect but it does not eliminate it.

The main advantage of having the DC-blocking function in the splitter unit is to prevent DC faults between the splitter and the ADSL modem affecting the POTS service. However DC faults having no AC effects in the voice band are rare, so the advantage of this solution appears limited.

Figure 3a and 3b are possible implementations of the DC-blocking function.

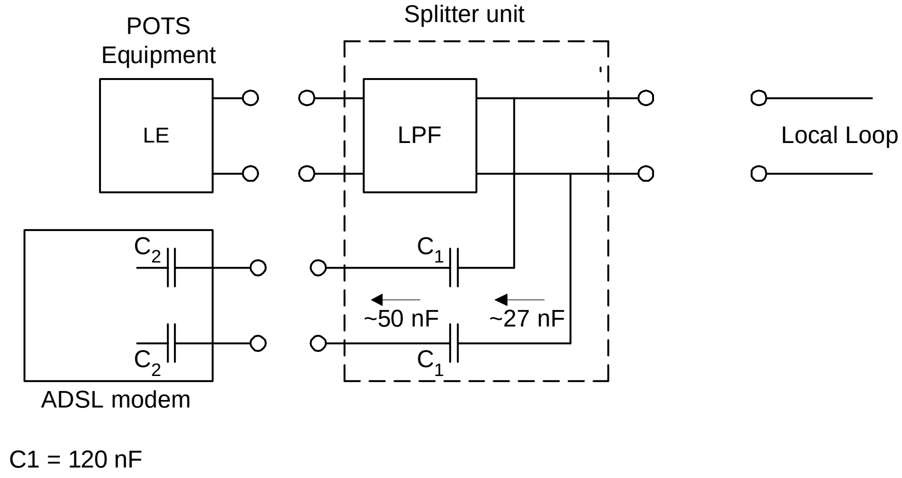


Figure 3a: Splitter unit with DC-blocking function (parallel solution)

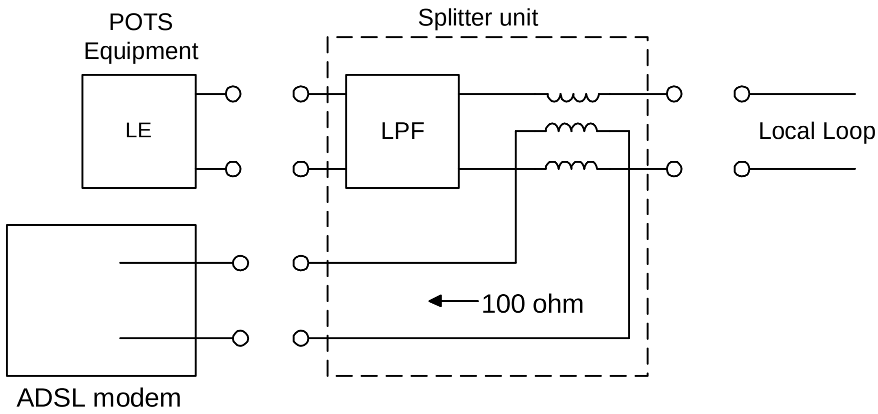


Figure 3b: Splitter unit with DC-blocking function (series solution)

A problem with the method described in figure 3b could be that the DC loop current passing through the transformer reduces its dynamic range and the possibly resulting non-linearity may cause intermodulation distortion to the DSL. A solution would be to use larger magnetic components resulting in a size and cost penalty.

4.4 LPF, DC-bloc and full HPF in the splitter unit

The solution shown in figure 4 is also suitable for the "unbundled" situation. The full HPF is in the splitter unit.

This option provides a good separation of services if the splitter is used by the operator of the access network. The ADSL and POTS operators have no access to each other's services. The responsibilities for the relevant services are more clearly allocated. The quality of the splitter is a matter of the access network operator.

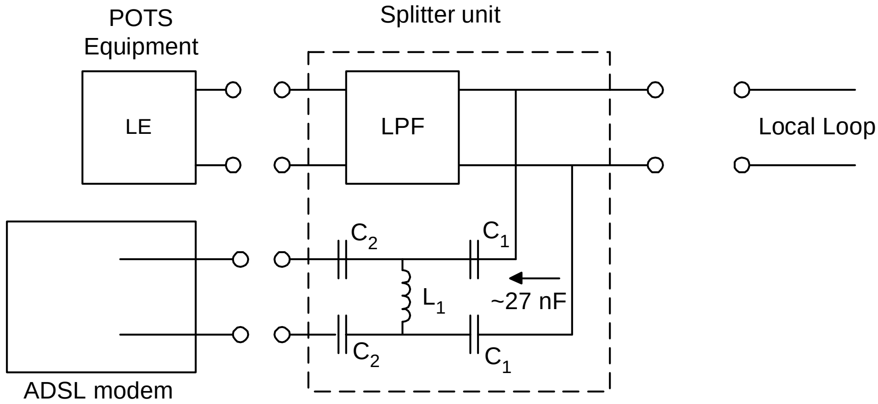
There is no risk of the bridged tap effect if there is a long cable between the splitter unit and the DSLAM.

The requirements for the HPF in the receiver of the ADSL modem may be relaxed thus allowing a possible cost saving.

The operator can only use the frequency band for the relevant service. This could be important if there is a difference in the cost of renting a line for an ADSL service only or for both services i.e. ADSL and POTS.

Compared with options 2 and 4 (figure 3 and figure 5), this option provides better isolation for the POTS service (from Line-port to ADSL-port).

A disadvantage with this option could be a cost penalty.



NOTE: For example, L1 is in the range of 0,38 mH, C1 is in the range of 54 nF and C2 is in the range of 90 nF. Further optimization of this example is possible.

Figure 4: Splitter unit with DC-blocking function and full HPF

To keep the power supply voltages used by the ADSL modem line driver low, it is common to use a step up transformer, where conveniently the inductance becomes the shunt impedance of the HPF. With the single choke arrangement shown, this beneficial twin use of the transformer is lost.

4.5 LPF, DC-bloc and part of HPF in splitter unit

The solution shown in figure 5 is also suitable for use in the "unbundled" situation. It is comparable with option 3 (figure 4) but it requires fewer matched capacitors.

This option provides a good separation of services if the splitter is used by the operator of the access network. The ADSL and POTS operators have no access to each other's services. The responsibilities for the relevant services are more clearly allocated. The quality of the splitter is a matter of the access network operator.

There is no risk of a bridged tap effect if there is a long cable between the splitter unit and the DSLAM.

The requirements for the HPF in the receiver of the ADSL modem may be relaxed thus allowing a possible cost saving.

The operator can only use the frequency band for the relevant service. This could be important if there is a difference in the cost of renting a line for an ADSL service only or for both services i.e. ADSL and POTS.

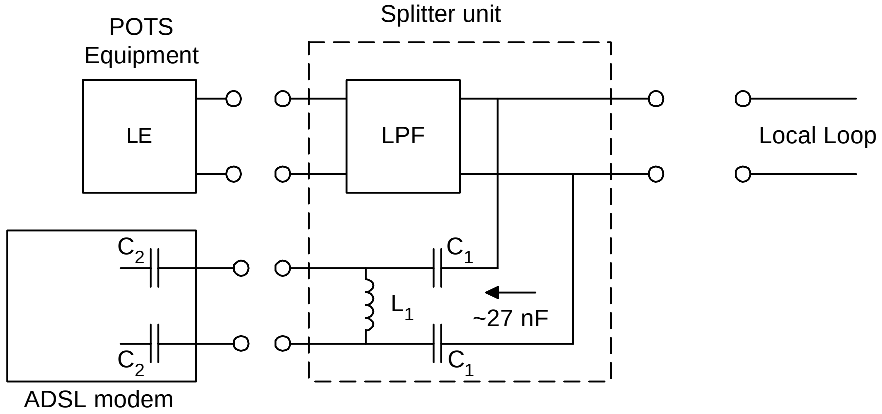
This solution would be more expensive than options 1 and 2 but less than option 3.

NOTE: If a center-tap is used both in the splitter unit (figure 3b) and in the ADSL modem, only one capacitor in the splitter unit and one in the ADSL modem are necessary as opposed to two pairs of matched capacitors. This implementation detail is not shown in figure 4.

The Insertion Loss of the part of the HPF that is in the splitter unit is in table 1. It is the Insertion Loss of the implementation example in figure 5

Table 1: Insertion Loss between Line-port and ADSL-port of the splitter unit of figure 5

Frequency	Insertion Loss (between 600 Ω)
1 kHz	63 dB
3 kHz	44 dB



NOTE: For example, L1 is in the range of 0,38 mH and C1 in the range of 54 nF. This example is intended to show the feasibility of the concept, further optimization is possible.

Figure 5: Splitter unit with LPF, DC-blocking function and partial HPF

4.6 Other aspects

Because of installation difficulties and costs for installing the user splitter, a so-called "Lite" version of ADSL (ITU-T Recommendation G.992.2 [6]) was developed with lower line speeds. With this system there is in principle no splitter at the users premises. To prevent bad performance in real operation, "micro-filters" are placed at some of the users POTS TEs. This arrangement of micro-filters is often called a "distributed splitter". Further developments have led to the distributed splitter arrangement being used also with full rate ADSL (ITU-T Recommendation G.992.1 [7]), in this case a filter is placed at each of the users POTS TEs. The intended application of the filters in the present document is **full rate ADSL** (the same application as with the common splitter).

NOTE 1: In case of a distributed splitter, a logical place for the DC-blocking function is in the ADSL transceiver (between the input and the HPF).

NOTE 2: Moving the DC-blocking function to the ADSL transceiver reduces the splitter from a 3 port device to a device with only 2 electrically different ports, because in this case the ADSL-port and the Line-port are connected together in the splitter box. This difference is important for the Longitudinal Balance test.

In order to fulfil the requirements (e.g. unbalance about earth) it is recommended to use a "balanced" design for the splitter.

5 Splitter requirements (Low pass part)

5.1 DC requirements

5.1.1 Polarity independence

The splitter(s) shall conform to all the applicable requirements of the present document for both polarities of the DC line feeding voltage (and the DC line current) provided by the local exchange.

This may not apply in the case where a "signature network", described in clause 7, is used as this may be polarity dependant.

5.1.2 DC resistance to earth

Splitters with an earth terminal shall have a sufficiently high resistance to earth. The DC resistance between each 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.

5.1.3 DC resistance between A-wire and B-wire

The DC resistance between the A-wire and B-wire terminal of the splitter, when tested with 100 V DC, shall not be less than 5 MΩ.

This requirement is not applicable if the splitter is equipped with a so called "signature network" (see clause 7.1), or if it is a splitter with active components which uses some feeding current from the line (this is called an "active splitter").

5.1.4 DC series resistance

The DC series resistance of the POTS port to the line port of one splitter should be less than 50 Ω. This requirement should be met for the feeding conditions described in clause 5.1.5.

NOTE: Access network test systems give a number of test results e.g. the "DC-isolation resistance to earth"; "estimation of loop length" is another common output result of such systems. A high DC series resistance may influence the accuracy of loop length estimation performed by a test system for local loops.

5.1.5 DC feeding current

The splitter shall fulfil all of the AC requirements in the voice band and for the ADSL band with a DC loop current in the range 0 mA to 80 mA, and all DC requirements with a DC loop current of 15 mA to 80 mA.

NOTE: Some older switching systems may operate at loop currents of 125 mA or even higher, but it is unlikely that new technologies (xDSL) are or can be used together with those older switching systems.

For networks using only constant current sources in their exchange line-cards, which typically provide DC feeding currents in the range 35 mA to 45 mA, the maximum DC current for the tests could be lower than 80 mA e.g. 45 mA or 50 mA.

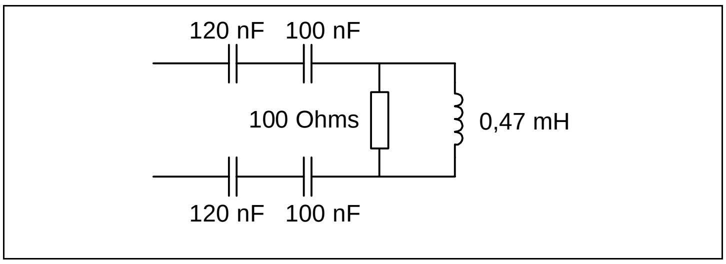
The current is provided by the test equipment or by a DC-feeding-bridge and a DC-termination.

5.2 Terminating impedances

5.2.1 Z_{ADSL}

In most of the tests with voice frequencies, the ADSL-port is terminated with an impedance called Z_{ADSL}. Z_{ADSL} represents an impedance equal to the input impedance of the ADSL transceiver (with the HPF), as seen from the splitter.

This impedance network is given in figure 6.



NOTE: This impedance is applicable for the scenario where the blocking capacitors are not fitted in the splitter as described in figure 2. Suitable impedance networks suitable for other options described in clause 4 are given in Annex B.

Figure 6: Schematic diagram of Z_{ADSL}

For practical tests at voice/POTS frequencies, a capacitor of 27 nF could be used instead of Z_{ADSL} with only a negligible error. In the long term it is expected that on lines where the ADSL service has been ceased, splitters will remain connected, as it will not be worthwhile for a network operator to dispatch staff to remove the user side splitter.

For this reason, it is required that the splitter also fulfils all the requirements if there is no ADSL load (the ADSL transceiver) connected to the splitter.

If the splitter is an integrated part of the ADSL transceiver, the ADSL port of the splitter is in general not physically accessible and testing has to be performed for the combined unit.

5.2.2 Z_R and Z_{SL}

For requirements relating to voice band frequencies described in the present document, the terminating impedances Z_R and Z_{SL} are used to terminate the POTS port or the line port. Z_R is the European harmonized complex impedance, Z_{SL} is an impedance used in TBR 38 [10] to simulate a short line terminated in 600 Ω.

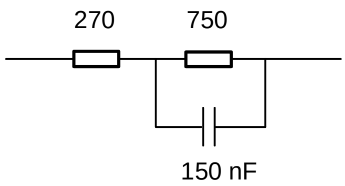


Figure 7: Z_R

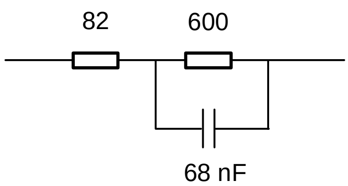


Figure 8: Z_{SL}

5.2.3 Z_{RHF}

For requirements relating to ADSL frequencies described in the present document, the terminating impedance Z_{RHF} is used to terminate POTS ports. This is the European harmonized complex impedance Z_R with the modification proposed in TR 102 139 [3]. This network is shown in figure 9.

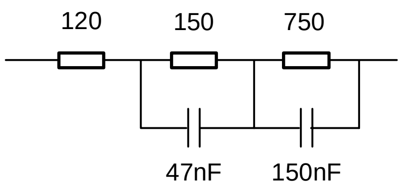


Figure 9: Impedance Z_{RHF}

NOTE: In practical applications of the voice band requirements Z_{RHF} may be used instead of Z_R as both terminations will be the same at these frequencies.

5.3 Pass band Loss requirements

5.3.1 Voltage drop at 25 Hz and 50 Hz

Ringing signals with frequencies of 25 Hz and 50 Hz should be used.

The maximum voltage drop at the load impedance due to the insertion of one splitter, in the test set-up of figure 10, shall be not more then 2 Vrms.

Table 2: Test conditions Insertion loss 25 Hz and 50 Hz

Impedance of signal source	850 Ω
Impedance of the load	4 000 Ω
Open voltage of the AC test signal source	60 Vrms
Level of the DC feeding voltage	60 V DC

NOTE: The ringing signal (ringing voltage) is in most cases superimposed on the DC feeding voltage. The maximum ringing signal may be as high as 100 Vrms and the maximum DC voltage may be as high as 78 V.

The splitter should be able to transfer the superimposed signals to the AC-load of 4 000 Ω without significant distortion.

5.3.2 Insertion loss

The insertion loss of one splitter shall be less then 1dB at 1kHz.

The Insertion Loss is the difference in loss with and without splitter.

The test set up is given in figure 10.

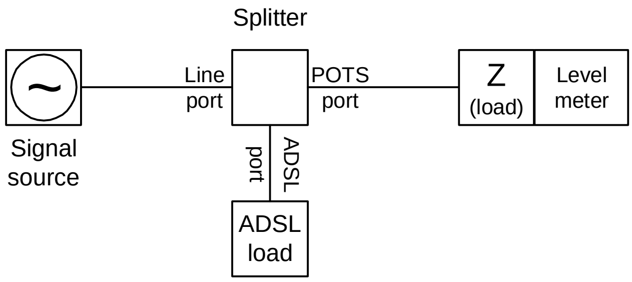


Figure 10: Test set up for Insertion Loss testing on a splitter

Level of the test signal = -4 dBV emf
The test should be executed with the combinations of source and load impedances in table 3. The DC feeding current is specified in clause 5.1.5.

Table 3: Combinations of Source and Load impedances for the Insertion Loss test

Source/Load Combination	Impedance of Signal source	Impedance of the load (Z in figure 10)
Combination 1	Z_R	Z_R
Combination 2	600 Ω	600 Ω

5.3.3 Insertion loss distortion

The absolute difference between the insertion loss at any frequency in the range 200 Hz to 4 000 Hz and the insertion loss at 1 kHz shall be less then 1dB.

The test should be executed with the combinations of source and load impedances in table 3. The test set-up is described in figure 10, the DC feeding current is specified in clause 5.1.5.

5.4 Impedance at 25 Hz and 50 Hz

The POTS-port and the line-port of the splitter should have an impedance at 25 Hz and 50 Hz of not less than 40 kΩ. While testing a port, all other ports are open (non terminated).

5.5 Impedance of splitters in the voice band

It is necessary to identify the desirable characteristics of POTS splitters required to operate satisfactorily in most European telecom networks. In other words, they should not significantly compromise the function of the existing balance of local exchange hybrid networks and of the sidetone networks of installed telephone sets.

Some European networks currently in operation are designed around 600 Ω, while others are designed around complex impedance terminations or are in a transitional phase between the two terminations. As a consequence it is not possible to specify a unique value for splitter impedances applicable to all European networks, but it must be required that splitters do not significantly disturb the existing impedances as seen both from the network side and from the terminal side.

Acknowledging that ideal transparency cannot be achieved, the term "**transparent**" is used in the present document to describe splitters which are intended to achieve this impedance transparency aim.

The term "**non transparent**" is used for splitters which do not belong to the category above and that are usually intended to present the optimized impedance for a specific network and, as such, can not be harmonized at the European level for the reasons explained above. In the present document the general principles for specifying this kind of splitters are provided in Annex A.

5.6 Impedance of " transparent" splitters

5.6.1 Impedance of a single (transparent) LE splitter

5.6.1.1 Impedance testing at the POTS-port

The test set-up is in figure 11. The DC feeding current is specified in clause 5.1.5. The requirements should be met with and without the ADSL port terminated.

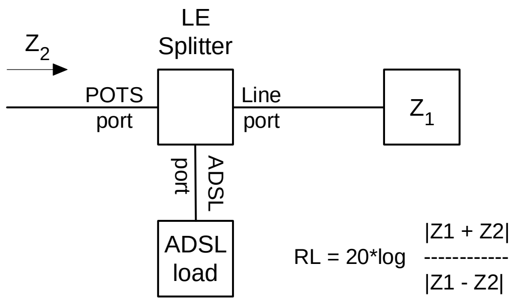


Figure 11: Impedance testing on a transparent LE splitter (at the POTS-port)

The Return Loss shall fulfil the requirements for all the tests of table 4.

Table 4: Return loss

Test #	Value of Z1	Frequency range	Minimum Return Loss
test 1	Z_{SL}	300 Hz to 3 400 Hz	12 dB (Note)
test 2	Z_{SL}	3 400 Hz to 4 000 Hz	8 dB
test 3	Z_R	300 Hz to 3 400 Hz	12 dB (Note)
test 4	Z_R	3 400 Hz to 4 000 Hz	8 dB
NOTE: A value of 14 dB for the minimum Return Loss instead of 12 dB is desirable.			

5.6.1.2 Impedance testing at the Line-port

The test set-up is in figure 12. The DC feeding current is specified in clause 5.1.5. The requirements should be met with and without the ADSL port terminated.

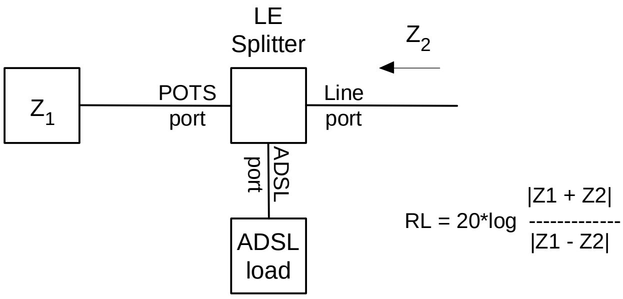


Figure 12: Impedance testing on a transparent LE splitter (at the Line port)

The Return Loss shall fulfil the requirements for all the tests of table 4.

5.6.2 Impedance of a single (transparent) Remote splitter

The Remote splitter is the splitter installed at the user's premises.

5.6.2.1 Impedance testing at the POTS-port

The test set-up is in figure 13. The DC feeding current is specified in clause 5.1. The requirements should be met with and without the ADSL port terminated.

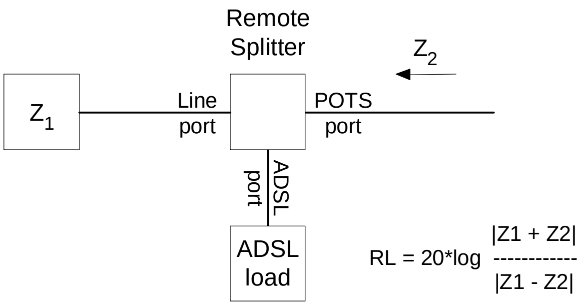


Figure 13: Impedance testing on a transparent Remote splitter (at the POTS-port)

The Return Loss shall fulfil the requirements of table 4.

5.6.2.2 Impedance testing at the Line-port

The test set-up is in figure 14. The DC feeding current is specified in clause 5.1. The requirements should be met with and without the ADSL port terminated.

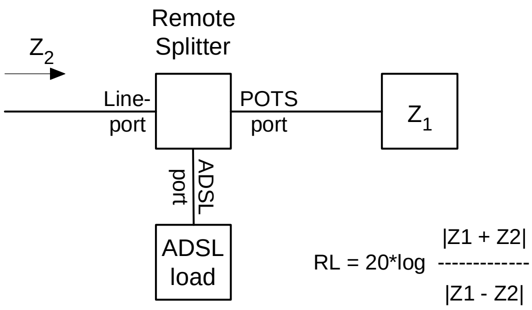


Figure 14: Impedance testing on a transparent Remote splitter (at the Line-port)

The Return Loss shall fulfil the requirements for all the tests of table 4.

5.7 Unbalance about earth

The impedance unbalance about earth is expressed as the Longitudinal Conversion Loss (LCL).

For the splitter, three slightly different tests can be distinguished:

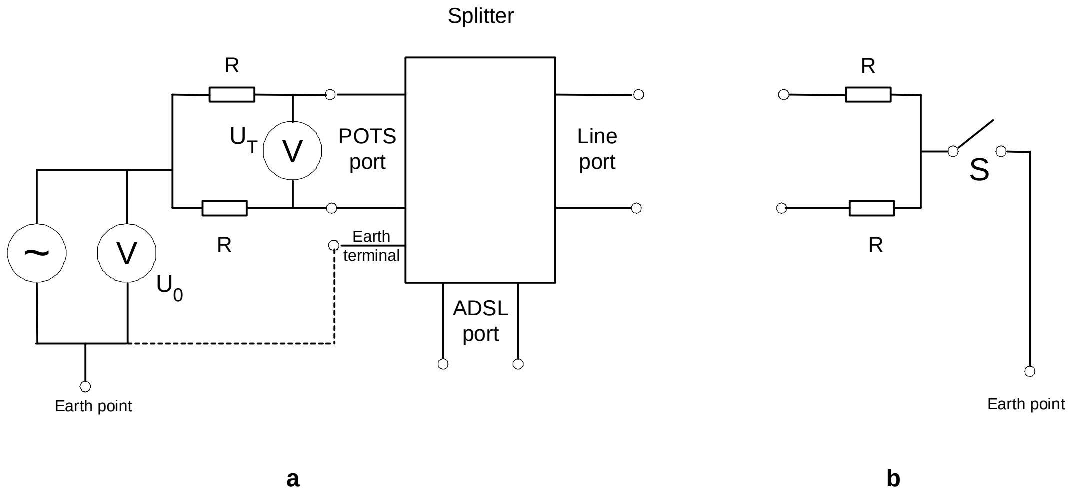
5.7.1 The two port test

This test is used for splitters with two electrically different ports e.g. the user splitter when the DC-blocking function is not build-in in the splitter but in the ADSL modem. The Line-port and ADSL-port are electrically the same for this type.

5.7.2 The three port test

Is used for splitters with three electrically different ports e.g. the user splitter when the DC-blocking function (see figure 3) is in the splitter.

The test set-up is in figure 15. The DC feeding current is specified in clause 5.1.5.



NOTE: The dotted circuit is only used if the splitter has an earth terminal.

Figure 15: LCL test set-up (a) and termination network (b)

The LCL is measured on all the ports (the figure shows measuring the POTS-port). When measuring one port, the other accessible port(s) are:

- terminated with the network in figure 15b with S = open;
- terminated with the network in figure 15b with S = closed.

If there are three ports, one is measured and the two remaining ports are terminated with terminations of figure 13(b) and the switches in any possible combination (2 terminated ports and the switches open or closed gives 4 combinations).

The LCL is calculated by using the following equation:

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

The splitter shall fulfil the requirements in table 5 for all ports and all combinations of terminations.

Table 5: Longitudinal Conversion Loss, minimum values

Frequency range	Value of R	Minimum LCL value
50 Hz to 600 Hz	600/2 Ω	40 dB
600 Hz to 3 400 Hz	600/2 Ω	46 dB
3 400 Hz to 4 000 Hz	600/2 Ω	40 dB
4 000 Hz to 10 MHz	100/2 Ω	40 dB

If the splitter has no earth terminal, the test should be performed while the splitter is placed on an earthed metal plate of a sufficiently large size.

The measurements should be made with a selective voltmeter, they should not be made at 50 Hz (mains frequency) or multiples of 50 Hz up to the 5^{th} harmonic.

5.8 Isolation (Insertion Loss) at 32 kHz to 1 100 kHz

As ADSL modems require quiet conditions on the line for ADSL frequencies, the splitter needs to isolate the POTS-port sufficiently from the ADSL-port and Line-port at these frequencies. The high Insertion Loss, required for this purpose is called isolation.

Although the ASDL frequency range starts at about 26 kHz, the Isolation of the splitter is specified up from 32 kHz. This because the difficulty to make a splitter which has already a very high Isolation (55 dB) at 26 kHz.

The ADSL frequency range is for Isolation is 32 kHz to 1 100 kHz for full rate ADSL (ITU-T Recommendation G.992.1 [7]).

It is assumed that no special Home LAN system (e.g. PNA) is used in the user's facility. In the case of deployment of such systems additional filtering is necessary.

It is believed that POTS terminal equipment can generate disturbances in the frequency band 200 kHz to 30 MHz at signal levels as high as -50 dBm in a 10 kHz bandwidth. Most existing home wiring installations were not designed to be used in conjunction with equipment operating at this frequency range, it is believed that there is a possibility of these frequencies being induced into the local environment affecting other lines and amateur radio installations.

The test set-up is in figure 16, the DC feeding current is specified in clause 5.1.5. The splitter shall fulfil the minimum Isolation requirements of table 6. The splitter shall also fulfil the requirement if the signal source is connected to the ADSL-port and the Line-port is terminated with Z_{RHF}.

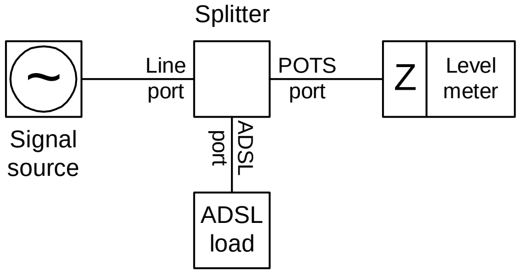


Figure 16: Test set up for Isolation testing on a splitter

Table 6: Isolation, minimum value

Frequency range	Minimum value
32 kHz to 1 100 kHz	55 dB

- Impedance of signal source = Z_{RHF}
- Impedance of the load = Z_{RHF}
- Level of the test signal = +16,7 dBV emf (this is comparable to +19,9 dBm in a load of 120 Ω; the impedance of Z_{RHF} approaches a value of 120 Ω at higher frequencies; the transmit level of the LE ADSL transceiver is +19,9 dBm).

NOTE 1: A particular advantage of the use of Z_{RHF} is that the Insertion Loss in the transition band between POTS to ADSL band is measured in an unambiguous way.

NOTE 2: The POTS ringing voltage (25 Hz or 50 Hz) should be sufficiently attenuated between the line and the ADSL transceiver input. This isolation is accomplished by the HPF (in the ADSL-transceiver).

NOTE 3: Further experience and investigations in this area may lead to some different results to be considered later.

The Isolation characteristic from POTS to the Line port and from POTS to the ADSL port is also important to protect ADSL from possible out-of-band signals generated by POTS terminals. For the moment this point (performance level and precise test methods) is under study.

5.9 Noise

The noise produced by a splitter itself (without signals applied to it) should be limited. Especially "active splitters" can produce noise. The DC feeding current is specified in clause 5.1.5.

5.9.1 Noise 300 Hz to 4 000 Hz

The noise in the range 300 Hz to 4 000 Hz, measured at the Line-port and the POTS-port of a splitter, should be less than -70 dBV and, measured with a psophometer, less than -75 dBVp.

Line-port and POTS-port should be terminated with Z_R.

The ADSL-port is terminated with the ADSL-load (Z_{ADSL}).

5.9.2 Noise 26 kHz to 1 100 kHz

The noise, in the frequency range 26 kHz to 1 100 kHz, measured at the "ADSL-port" and "Line-port" should be less than -70 dBm measured in each bandwidth of 10 kHz, this is equal to -110 dBm/Hz.

Line-port, POTS-port and ADSL-port should be terminated with Z_{RHF}.

5.10 Distortion & Intermodulation

The harmonic distortion and possible intermodulation, with as result transferring of ADSL signal energy into the voice band, should be low to prevent degradation of the voice service. This could happen in case of non-linearities in the splitter (e.g. behaviour of coils or semiconductor devices).

5.10.1 Distortion

Applied to the splitter are:

- a 1 020 Hz signal at the Line-port at a level of -9 dBV into Z_R;
- an ADSL signal (or an artificial equivalent with sufficient PAR) at the ADSL-port (simulating the local modem). The level of the signal is +12,5 dBm (ADSL upstream signal);
- an ADSL signal at the Line-port (simulating the other modem via a short Local Loop). The level of the signal is +19,9 dBm (ADSL downstream signal).

The distortion and noise should be measured at the POTS-port with a noise meter with a 1 020 Hz notch filter (ITU-T Recommendation O.132 [5]).

The total power of distortion and noise in the frequency range 300 Hz to 4 000 Hz shall be less than -60 dBV.

The splitter shall fulfil the requirement when tested with DC line currents in the range described in clause 5.1.5.

5.10.2 Intermodulation

The DC feeding current is specified in clause 5.1.

The following test signals are applied to the splitter:

- A 4-tone test signal at the Line-port (from ITU-T Recommendation O.42 [4]).
- An ADSL signal (or an artificial equivalent with sufficient PAR) at the ADSL-port (simulating the local modem). The level of the signal is +12,5 dBm (ADSL upstream signal).
- An ADSL signal at the Line-port (simulating the other modem via a short Local Loop). The level of the signal is +19,9 dBm (ADSL downstream signal).

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

Requirement: Using the 4-tone method at a level of –9 dBm, the second and third order harmonic distortion products shall be at least 57 dB and 60 dB, respectively below the received signal level.

5.11 Group Delay Distortion

The increase of the delay distortion by inserting one splitter as depicted in figure 17 should be less than the figures in table 7, relative to the lowest measured delay in the frequency range 300 Hz to 4 000 Hz.

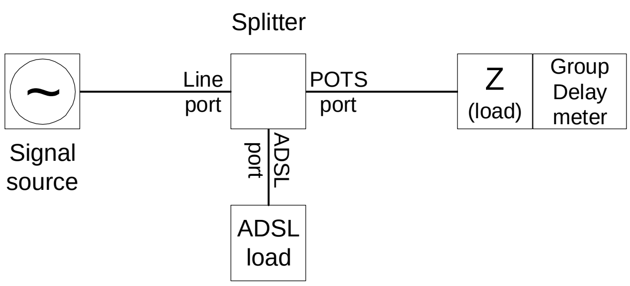


Figure 17: Test set up for Group Delay Distortion testing on a splitter

Table 7: Group Delay Distortion, maximum values

Frequency range	**Maximum value (in µs)**
200 Hz to 600 Hz	250 µs
600 Hz to 3 200 Hz	200 µs
3 200 Hz to 4 000 Hz	250 µs

- Impedance of signal source = 600 Ω/Z_R.
- Impedance of the load = 600 Ω/Z_R.
- Level of the test signal = -10 dBV.

5.12 Metering at 12 kHz or 16 kHz

Some network operators use 12 kHz or 16 kHz to provide metering or advice of charge information for the POTS service. These signals are transmitted at high signal levels using relatively low source and load impedances resulting in higher than normal signal currents.

Support of 12 kHz or 16 kHz metering by a splitter reduces the frequency band available for the transition from the low attenuation range (POTS band) to the high attenuation range (ADSL band) significantly. This decrease requires a more complex filter to fulfil the Insertion Loss and the Isolation requirements. It is therefore recommended that operators activating xDSL systems deactivate the metering pulses facility where feasible, in which case a requirement for insertion loss at these frequencies will not be necessary. However it is recognized that in some networks these metering signals cannot be removed, in these cases a requirement for insertion loss at these frequencies will be necessary.

It should also be noted that a TE designed to TBR 21 [11] and EN 301 437 [8] may be disturbed by metering signals if an appropriate 12 kHz or 16 kHz blocking filter is not installed, as immunity to metering signals is outside the scope of these standards. Information on 12 kHz or 16 kHz blocking is found in EG 201 120 [2], clause B.3.

Another problem is that the ADSL transceiver possibly needs a better input filter to deal with the high level of the 12 kHz or 16 kHz signal on its receiver input.

Test set up of figure 10 is used. The maximum insertion loss of one splitter at a frequency of 12 kHz ±1 % or at a frequency of 16 kHz ±1 %, shall be 3 dB.

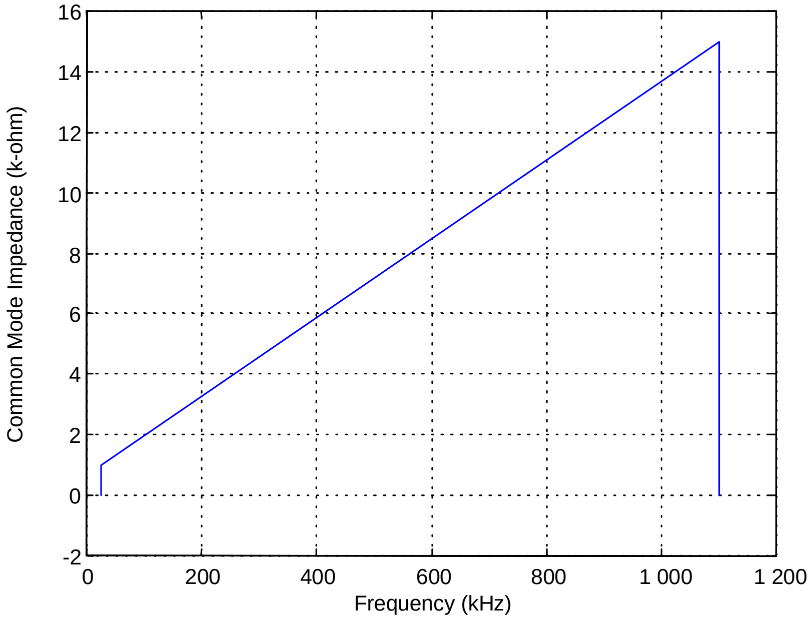
- Impedance of the source: 200 Ω.
- Impedance of the Load: 200 Ω.
- Level of the test signal: 5 Vrms.

5.13 Common Mode Impedance

POTS terminals may produce common mode impulses which will pass through a differential mode filter and cause errors in the DSL modem. This may happen when going "on/off hook", POTS line cards may produce them at the start/stop of the ringing cadence. Another source of troublesome common mode signal can be from switched mode power supplies as typically used in fax machines and laptops. A common mode filter is required to reduce these problems.

The common mode choke (coil) should be constructed such that the resonance between its inductance and interwinding capacitance is placed in the middle of the DSL band.

The modulus of the impedance of the common mode choke measured with the terminals shorted at both ports, should exceed the values indicated in the mask shown in figure 18.



NOTE: The vertical lines of the mask are at 25 kHz and 1 100 kHz.

Figure 18: Mask for the minimum Common Mode Impedance

NOTE: Further experience and investigations in this area may lead to some different results to be considered later.

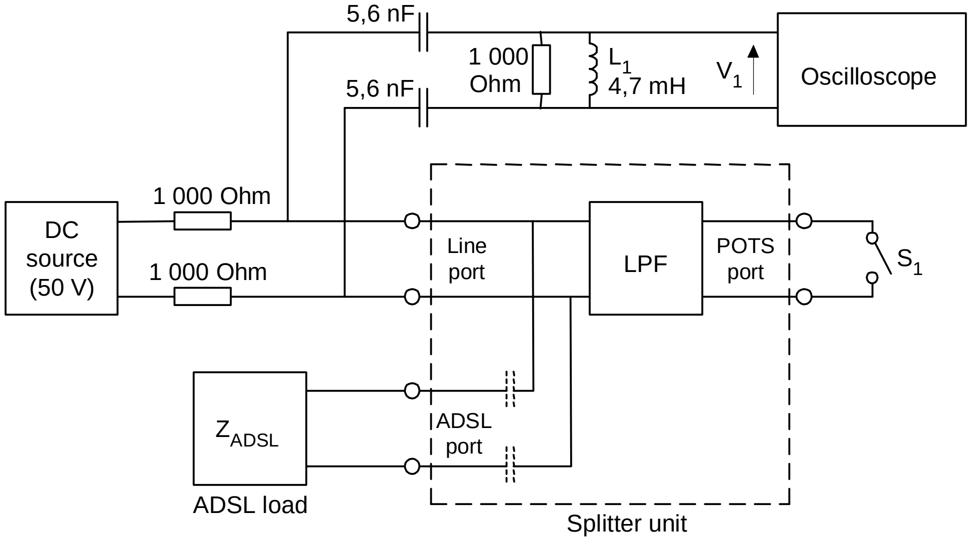
5.14 Immunity to high level POTS signals

An important requirement of a POTS filter is to prevent frequencies in the pass-band of the DSL modem HPF being generated due to the presence of high voltage signals/transients present on the line. The effect of such frequencies on the modem can be twofold. The high voltage swing on the line generates a corresponding high voltage signal at the receiver of the modem which can, at the very least, make the receiver go non-linear. At worst it can cause clipping. The other effect is that the frequency content of the high voltage swing will overlap the frequencies used for the upstream transmission, causing a reduction of signal to noise ratio for the carriers and hence increased error rate.

High voltage swings are created under a number of circumstances. The obvious condition is when a telephone goes off-hook or goes back on-hook. Loop disconnect dialling also causes high voltage swings. Indeed older telephones literally short out the line. High voltage swings also occur at the line card of the local exchange when line reversal is used. Thus measurement of the large signal performance is necessary for both the LE and remote filters.

The test set-up is shown in figure 19. The circuit is completely balanced. It consists of a semiconductor switch with an on/off transition time less than 2 µs on the POTS port. The line port is terminated with a simple resistive feeding bridge as used in ES 201 187 [9]. The line side is also terminated with Z_{ADSL}.

Requirement: The signal V1 measured across the 1 000 Ω of the Z_{ADSL} due to each change of state of the switch S1 should be less than 2V p-p and have a resonant frequency less than 15 kHz. This applies to both the on and off hook transitions of switch 1.



NOTE: By using a transformer for its inductance, the signal can be measured using an unbalanced oscilloscope.

Figure 19: Test circuit for large signal test

A possible implementation of S1 could be as follows: Since the filter is likely to be balanced, the semiconductor switch needs to be balanced. This means that it has to be driven from a floating supply. The following circuit has been successfully used to accomplish this requirement.

It uses a FET switch with the source and drain between tip and ring. The gate is driven from an opto-coupler powered by a 9V battery. The optical input to the coupler can be safely driven from unbalanced earthed equipment such as a pulse generator.

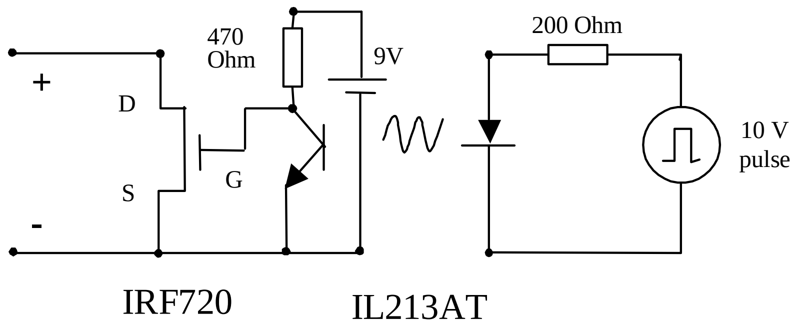


Figure 20: Possible implementation of S_1

With the circuit presented, it is important to maintain the polarity of the battery voltage through the filter to the FET switch. Putting the switch inside a bridge rectifier makes the circuit polarity insensitive. The drive to the LED and load on the collector of the opto-coupler have been chosen for the devices used to turn the FET on hard without excessive draining of the battery. The pulse generator can be repetitive and be used to trigger the scope.

The step response of a filter depends its load impedance. The load presented in the measurement circuit consists of Z_{ADSL} shunted by the feed resistance. A simple resistive battery feed was used to prevent the behaviour of the feed circuit from complicating the measurement. For instance, an inductive feed circuit causes significant ringing of the on/off hook response, as does a reasonable length of cable.

6 Distributed filters (additional requirements)

Due to difficulties and the costs involved with installing the remote splitter at the users premises and the developments and experiences with G.Lite, (ITU-T Recommendation G.992.2 [6]) the idea has been developed to install a small filter at each connected TE instead of one central splitter. The expectation is that this could be done by the user. **The goal application of the filter(s) described in the present document is full rate ADSL (ITU-T Recommendation G.992.1 [7]).**

Because those filters are connected in parallel at the "in house cabling", all the filters can be seen as a number of parallel connected loads to the line (for voice signals).

Also for ADSL frequencies, the configuration can be seen as a number of parallel loads for the ADSL signals.

The load of all the filters together can influence the impedances, resulting in an influence on the voice quality.

Because of the number of parallel connected filters depends on the users installation and cabling (number of POTS TEs in the house), the impedance performance could be different for each situation.

As a solution to the effects of the poor impedance behaviour in cases where there are a number of filters.

As a solution to the effects of the poor impedance behaviour in cases where there are a number of filters, some manufacturers are working on the development of filters which change their behaviour, depending on the fact that the connected TE is in the loop state or not. The name "dynamic filter" is used for such devices.

For this reason, more attention is paid to describe the DC conditions in the tests in this clause.

The requirements in this clause are additional to those in the clauses on "transparent" filters.

Because the behaviour of the filters depends on the number of installed filters, the manufacturer has to declare the maximum number of filters (N) which can be connected in parallel on a user's installation so that the total arrangement is still within the requirements (e.g. impedance requirements).

This configuration with small filters is called distributed splitter and is only used at the users premises.

6.1 DC requirements

Due to the fact that in the case of distributed filters, there will most likely be a number of them connected in parallel (see figure 21) the additional DC requirements described in the following clauses will apply.

6.1.1 DC resistance to earth

Splitters with an earth terminal shall have a sufficiently high resistance to earth. The DC resistance between each terminal (i.e. A-wire and B-wire) of the splitter and earth, when tested with 100 V DC, shall not be less than 100 MΩ.

6.1.2 DC resistance between A-wire and B-wire

The DC resistance between the A-wire and B-wire terminal of the splitter, when tested with 100 V DC, shall not be less than 25 MΩ.

6.2 Pass band

6.2.1 Insertion Loss at 25 Hz and 50 Hz

A filter should have a sufficient low Insertion Loss for 25 Hz and 50 Hz ringing signals. The connected TE is in the quiescent state during ringing.

The filter should fulfil the Insertion Loss requirement of clause 5.3.1 while there is a DC current in the range 0 mA to 0,5 mA (representing the quiescent state of the line).

6.2.2 Insertion loss

The same requirement as in clause 5.3.2 applies.

A test configuration is described in figure 21. The DC feeding current is specified in clause 5.1.5.

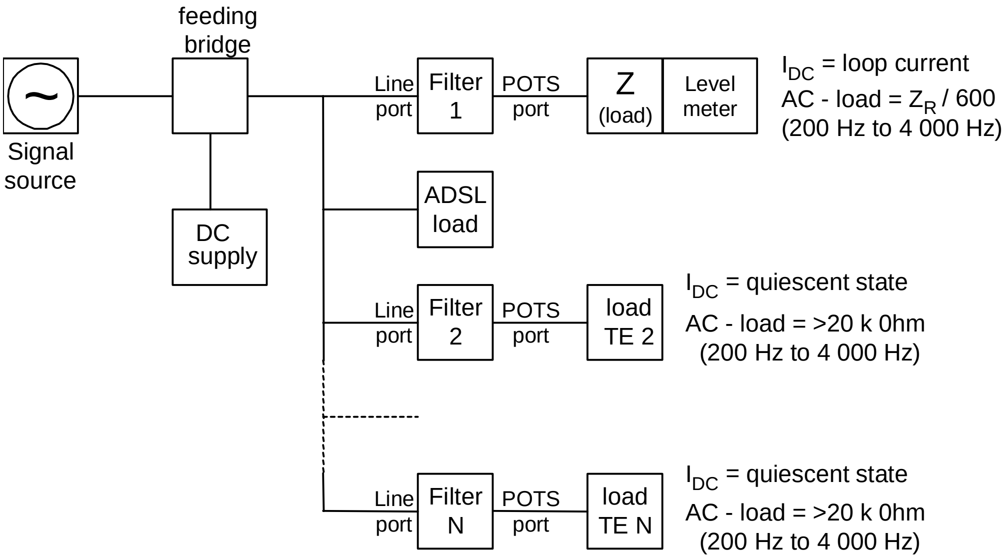


Figure 21: Test set up for Insertion Loss

- Impedance of the source: Z_R/600 Ω.
- Impedance of the Load: Z_R/600 Ω or > 20 kΩ (see figure).
- Level of the test signal: -4 dBV emf.

6.2.3 Insertion loss distortion

The absolute difference between the insertion loss at any frequency in the range 200 Hz to 4 000 Hz and the insertion loss at 1 kHz shall be less then 1dB.

A test configuration is described in figure 21.

6.3 Impedance of distributed (remote) filters

6.3.1 Impedance testing at the POTS-port

A test configuration is presented in figure 22. The DC feeding current is specified in clause 5.1.5.

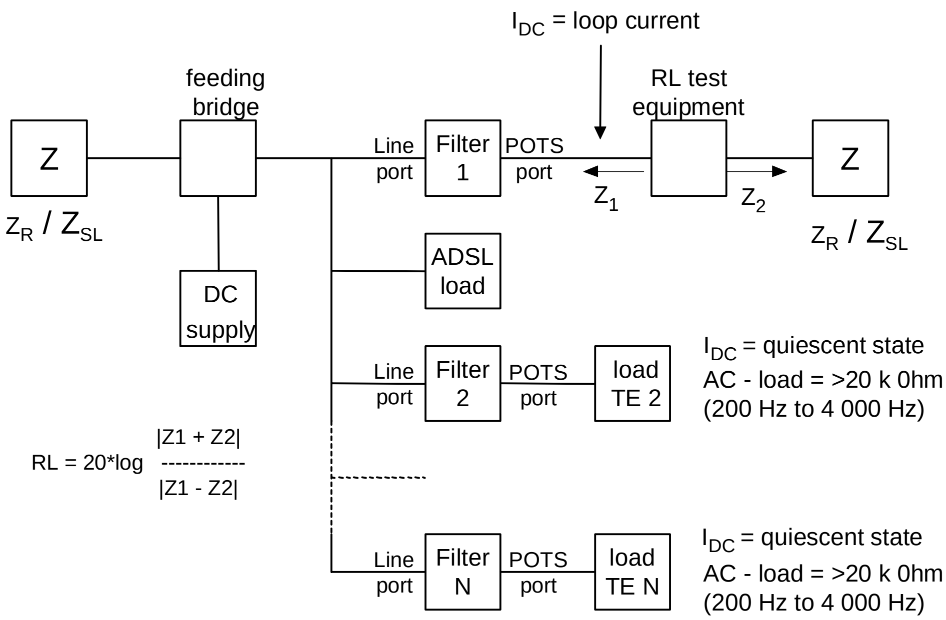


Figure 22: Impedance testing on distributed filters (at the POTS port)

The Return Loss shall fulfil the requirements for all the tests of table 4 in clause 5.6.1.1.

The manufacturer shall declare with which maximum number of filters (N) in parallel the requirements are still fulfilled.

6.3.2 Impedance testing at the Line-port

A test configuration is presented in figure 23, the DC feeding current is specified in clause 5.1.5.

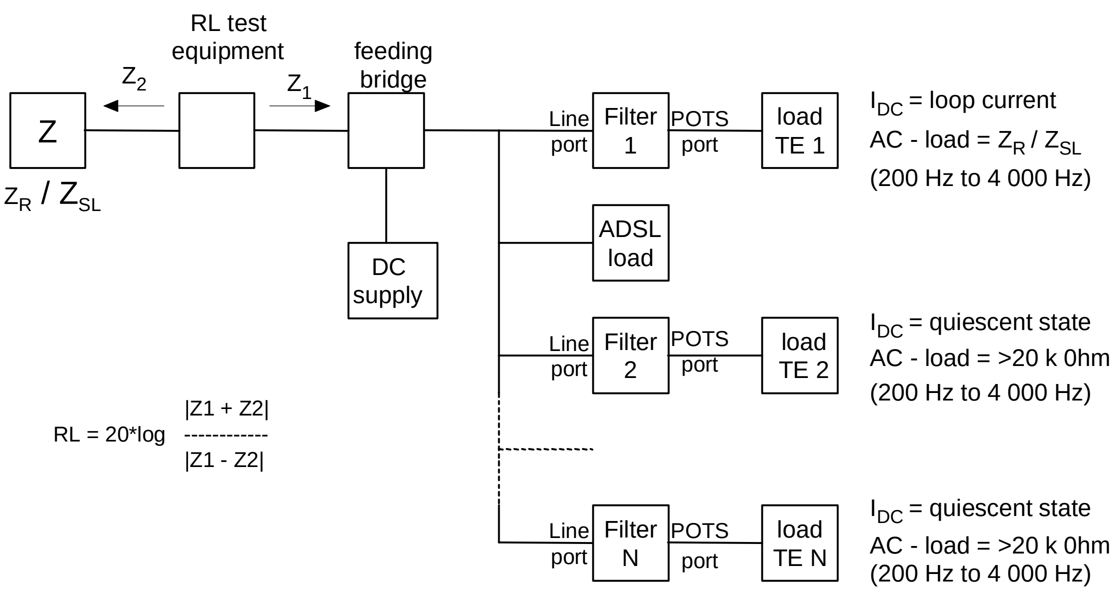


Figure 23: Impedance testing on distributed filters (at the Line port)

The Return Loss shall fulfil the requirements for all the tests of table 4 in clause 5.6.1.1.

6.4 Unbalance about earth

Unbalance about earth of a single filter is tested with the test method of clause 5.7. For filters with dynamic behaviour (dependant on the DC current) the filter shall fulfil the requirements with the DC feeding current is specified in clause 5.1.5.

6.5 Isolation (Insertion Loss) at 32 kHz to 1 100 kHz

Using the test configuration is described in figure 21 and the DC feeding current as specified in clause 5.1.5. The isolation requirements of clause 5.9 should be fulfilled.

6.6 Line side impedance of low pass filter at ADSL frequencies (32 kHz to 1 100 kHz)

The low pass filter should present an impedance to the line side of at least 1 000 Ω for the frequency range 26 kHz to 1 100 kHz. Thus requirement should apply with the POTS port terminated in $Z_{RHF.}$

6.7 Installation of filters

It is recommended that the filter be clearly marked to indicate which port connects to line and which to phone, in order to prevent incorrect user installation.

NOTE: This does not apply to filters which are reversible because both ports are electrically equal. It is however expected that it could be difficult to make filters which are reversible and fulfilling all the requirements.

7 Other requirements

7.1 "Signature network" for maintenance purposes

Some operators are using a test system for their POTS lines.

It could be beneficial to add a "Signature network" to the splitters to enable the test system to recognize the splitters in a line.

Examples signature networks are in figures 24 and 25.

The signatures are located on the POTS-port side of the splitters.

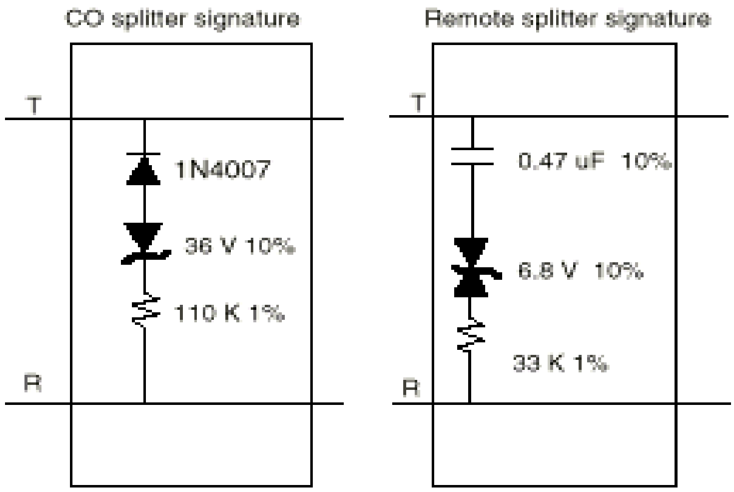
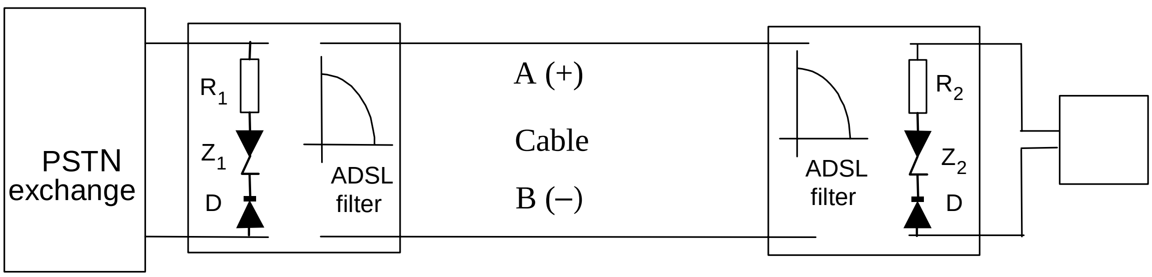


Figure 24: Splitter signature network for test and maintenance purposes, according to ANSI



R_1 = 107 kΩ; Z_1 = 24 V; Z_2 = 24 V; D = silicon diode (e.g. 1N4007)
R_2 = 130 kΩ (for active splitters)
R_2 = 215 kΩ (for passive splitters)
R_2 = 467 kΩ (for special purposes)
Tolerance of R_1, R_2, Z_1, Z_2 should be at least 1 % (or better)

Figure 25: Splitter signature network for test and maintenance purposes, developed for a DC based test method

In case of a distributed splitter it is difficult to use a signature, because there are a number of parallel connected filters. With a signature in every filter is impossible for the test system to draw suitable conclusions. To have only one filter with and all the other without a signature is a good theoretical solution but it is very likely that this would not work in practice.

For this reason it is recommended not to use a signature (at the users premises) in case of filters.

7.2 Line tests

It is known that particularly in cases of unbundled local loops some difficulties arise from testing the access lines, e.g. who & how is testing which facility and what impact does this testing have on other services sharing the physical line.

Annex A: Impedance of "non-transparent" splitters

Non-Transparent splitters are seen as a solution for special cases where a network operator specifies a unique terminating impedance that is the optimum for the network in question. For the purposes of this clause this impedance can be called $Z_{NETWORK}$. There can be cost aspects.

A.1 Impedance of a single "non transparent" LE splitter

A.1.1 Impedance of a single (non transparent) LE splitter

A.1.1.1 Impedance testing at the POTS-port: LE Splitter

The test set-up is in figure A.1, the DC feeding current is specified in clause 5.1.5, the requirements should be met with and without the ADSL port terminated.

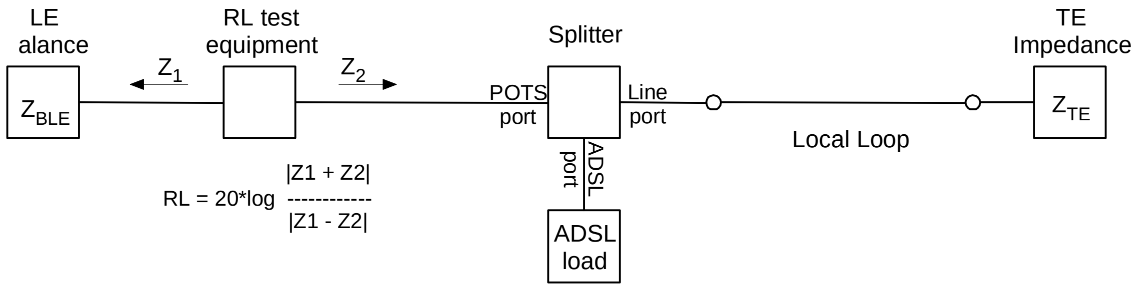


Figure A.1: Impedance testing on a non-transparent LE splitter (at the POTS-port)

The Return Loss shall fulfil the requirements of table A.1. Z_{TE}, Z_{BLE} and the local loop should be specified by the network operator in question.

Table A.1: Return loss

Test #	Value of Z1 (= Z_{TE} or Z_{LE} in the figures)	Frequency range	Minimum Return Loss
Test 1	$Z_{NETWORK}$	300 Hz to 3 400 Hz	14 dB
NOTE: It is recommended that a return loss requirement of 6 dB relative to Z_R should still be met in order to ensure stability if TBR 21 [11] designed TE is used. See stability technical details in TBR 21 [11] clause 4.7.2 and/or TBR 38 [10], Annex A, clause A.2.7.			

A.1.1.2 Impedance testing at the Line-port: LE splitter

The test set-up is in figure A.2, the DC feeding current is specified in clause 5.1.5, the requirements should be met with and without the ADSL port terminated.

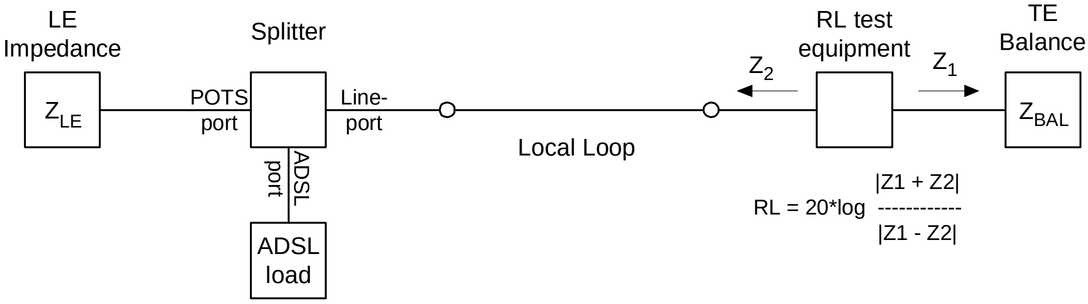


Figure A.2: Impedance testing on a non-transparent LE splitter (at the Line port)

The Return Loss shall fulfil the requirements of table A.1. Z_{BAL}, Z_{LE} and the local loop should be specified by the network operator in question.

A.1.2 Impedance of a single (non transparent) Remote splitter

The Remote splitter is the splitter installed at the user's premises.

A.1.2.1 Impedance testing at the POTS-port: remote splitter

The test set-up is in figure A.3, the DC feeding current is specified in clause 5.1.5, the requirements should be met with and without the ADSL port terminated.

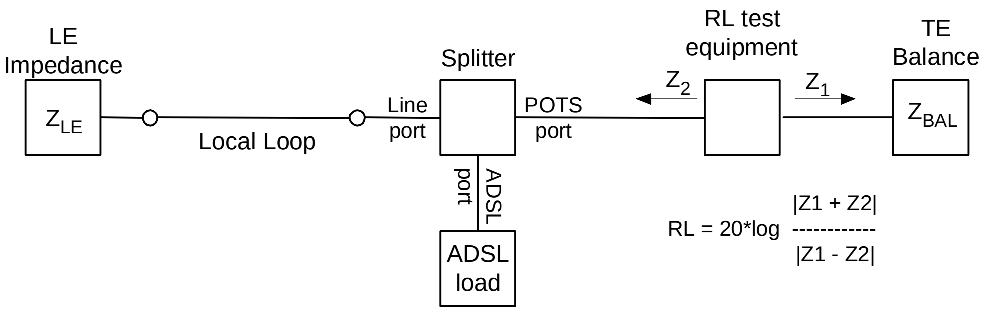


Figure A.3: Impedance testing on a non transparent Remote splitter (at the POTS-port)

The Return Loss shall fulfil the requirements of table A.1. Z_{BAL}, Z_{LE} and the local loop should be specified by the network operator in question.

A.1.2.2 Impedance testing at the Line-port: remote splitter

The test set-up is in figure A.4, the DC feeding current is specified in clause 5.1, the requirements should be met with and without the ADSL port terminated.

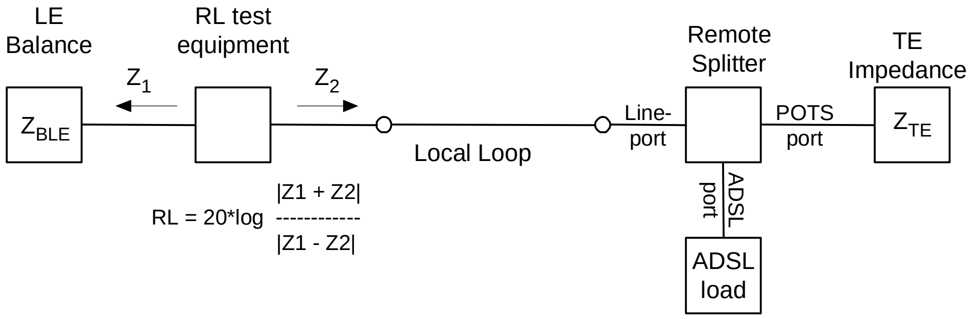


Figure A.4: Impedance testing on a non-transparent Remote splitter (at the Line-port)

The Return Loss shall fulfil the requirements of table A.1. Z_{BAL}, Z_{LE} and the local loop should be specified by the network operator in question.

Annex B: Z_{ADSL} options for different splitter designs

Clause 5.2.1 describes an impedance network for Z_{ADSL} that is applicable in the case where the DC blocking capacitors are not located in the splitter (clause 4.2). However other implementations are possible that may be suitable for different scenarios for example in the case of unbundled local loop. Examples of these scenarios are given in clauses 4.3 and 4.5. For these cases Z_{ADSL} is modified as follows.

B.1 LPF and DC-bloc in splitter unit (HPF in ADSL modem)

Figure B.1 shows the Z_{ADSL} network that would be suitable for use with the splitter described in clause 4.3, figure 3a.

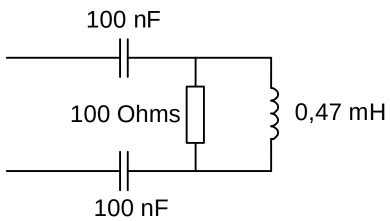


Figure B.1: Z_{ADSL} network compatible with clause 4.3 (figure 3a). For the splitter option shown in clause 4.3 (figure 3b) Z_{ADSL} will be 100 Ω

B.2 LPF, DC-bloc and full HPF in the splitter unit

For the scenario described in clause 4.4, (figure 4) a suitable value for Z_{ADSL} would be 100Ω.

B.3 LPF, DC-bloc and part of HPF in splitter unit

For the scenario described in clause 4.5, (figure 5) a suitable value for Z_{ADSL} would be 27 nF for the voice band frequencies.

History

Document history		
V1.1.1	December 2000	Publication