ETSI TS 101 388 V1.2.1 (2001-10)

Technical Specification

Transmission and Multiplexing (TM);
Access transmission systems on metallic access cables;
Asymmetric Digital Subscriber Line (ADSL) -
European specific requirements
[ITU-T G.992.1 modified]

Reference

RTS/TM-06006

Keywords

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Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Transmission and Multiplexing (TM).

It is necessary to read the present document in conjunction with ITU-T Recommendation G.992.1 [2] which is considered to be endorsed and modified by the requirements contained herein.

1 Scope

The present document specifies European requirements for ADSL.

The definition of new line codes and/or transmission systems is outside the scope of the present document.

The present document endorses ITU-T Recommendation G.992.1 [2], the contents of which apply with the modifications being covered herein. In particular the aspects covered by the present document are related to:

1) Methods to allow the simultaneous delivery of ADSL and ISDN-BA services [1] on the single pair. For example the techniques and redefinition of the ADSL signals/parameters as defined in ITU-T Recommendation G.992.1 [2] to allow ISDN-BA baseband signals to occupy frequencies below ADSL (from here onwards referred as out-of-band transport).

2) Performance Objectives and Test methods for ADSL over POTS/ISDN-BA.

3) TS 102 080 [1] backward compatibility.

4) Power feeding for the transported ISDN-BA.

5) Latency.

6) ISDN-BA splitter characteristics.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- 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.
- For a non-specific reference, the latest version applies.

[1] ETSI TS 102 080 (V1.3.1): "Transmission and Multiplexing (TM); Integrated Services Digital Network (ISDN) basic rate access; Digital transmission system on metallic local lines".

[2] ITU-T Recommendation G.992.1 (1999): "Asymmetric Digital Subscriber Line (ADSL) transceivers".

[3] Void.

[4] ETSI EN 300 001 (V1.5.1): "Attachments to the Public Switched Telephone Network (PSTN); General technical requirements for equipment connected to an analogue subscriber interface in the PSTN".

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

[6] ETSI TR 101 728 (V1.1.1): "Access and Terminals (AT); Study for the specification of the low pass section of POTS/ADSL splitters".

[7] ITU-T Recommendation G.996.1 (1999): "Test procedures for digital subscriber line (DSL) transceivers".

[8] ITU-T Recommendation G.117 (1996): "Transmission aspects of unbalance about earth".

[9] ANSI T1.413: "Network to Customer Installation Interfaces - Asymmetric Digital Subscriber Line (ADSL) Metallic Interface".

3 Definitions and abbreviations

3.1 Definitions

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

characteristic impedance (Z_0): property of homogeneous cables that is cable dependent

NOTE 1: This impedance value can be observed as input impedance, when the other end of the cable is terminated with a load having the same impedance Z_0.

design impedance (R_V): target input and output impedance of the ADSL modem

NOTE 2: This is 100 Ω for ADSL modems.

downstream: high speed digital data channel(s) in the direction of ALT towards ANT (network to customer premises)

EC ADSL over ISDN: refers to ADSL systems, using overlapped spectra, configured to allow delivery of ISDN-BA or POTS on the same pair

NOTE 3: EC ADSL over ISDN systems are configured as described in annex B of ITU-T Recommendation G.992.1.

EC ADSL over POTS: refers to ADSL systems, using overlapped spectra, configured to allow delivery of POTS on the same pair

NOTE 4: EC ADSL over POTS systems are configured as described for over lapped PSD masks in annex A of ITU-T Recommendation G.992.1.

electrical length: insertion loss for a loop at a given test frequency f_T, normalized to the reference impedance of 135 Ω

FDD ADSL over ISDN: refers to ADSL systems, using reduced NEXT spectra, configured to allow delivery of ISDN-BA or POTS on the same pair

NOTE 5: FDD ADSL over ISDN systems are configured as described in annex A of ITU-T Recommendation G.992.1, but using the downstream PSD mask described in clause 4.2.2.1.

FDD ADSL over POTS: refers to ADSL systems, using reduced NEXT spectra, configured to allow delivery of POTS on the same pair

NOTE 6: FDD ADSL over POTS systems are configured as described in annex A of ITU-T Recommendation G.992.1.

upstream: high speed digital data channel(s) in the direction of ANT towards ALT (customer premises to network)

Reference impedance (R_N): chosen impedance used for specifying transmission and reflection characteristics of cables and testloops

NOTE 7: ETSI has normalized this value at 135 Ω for a wide range of xDSL performance and conformance tests, including ADSL tests. This value is considered as being a reasonable average of characteristic impedances (Z_0) observed for a wide range of commonly used European distribution cables.

3.2 Abbreviations

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

2B1Q	Baseband linecode for ISDN-BA (4-PAM)
4B3T	Alternative ISDN-BA baseband linecode with wider frequency spectrum than 2B1Q
ADSL	Asymmetrical Digital Subscriber Line
ALT	ADSL Line Termination
ANT	ADSL Network Termination
ATM	Asynchronous Transfer Mode
ATU-C	ADSL Terminal Unit-Central office
ATU-R	ADSL Terminal Unit-Remote
ISDN-BA	Integrated Service Digital Network Basic rate Access
EC	Echo Cancelled
FDD	Frequency Division Duplexing
FEXT	Far End crossTalk
IDFT	Inverse Discrete Fourier Transform
ISDN	Integrated Services Digital Network
LTU	Line Termination Unit
NEXT	Near End crossTalk
NTU	Network Termination Unit
POTS	Plain Old Telephone Service
PRU	Pseudo-Random Upstream
PSD	Power Spectral Density (single sided)
STM	Synchronous Transfer Mode

4 Configuration of ADSL

4.1 Methods for configuring ADSL over POTS

The methods for configuring ADSL over POTS are as described in ITU-T Recommendation G.992.1 [2]. Additional constraints on ADSL over POTS operation are specified in clauses 4.1.1 and 4.1.2.

4.1.1 EC ADSL over POTS

EC ADSL over POTS shall comply with the requirements in annex A of ITU-T Recommendation G.992.1 [2]. The upstream transmission shall comply with the transmit spectral mask in clause A.2.4 of ITU-T Recommendation G.992.1 [2] (reproduced in clause D.3). The downstream transmission shall comply with the transmit spectral mask in clause A.1.2 of ITU-T Recommendation G.992.1 [2] (reproduced in clause D.1).

4.1.2 FDD ADSL over POTS

FDD ADSL over POTS shall comply with the requirements in annex A of ITU-T Recommendation G.992.1 [2]. The upstream transmission shall comply with the transmit spectral mask in clause A.2.4 of ITU-T Recommendation G.992.1 [2] (reproduced in clause D.3). The downstream transmission shall comply with the transmit spectral mask in clause A.1.3 of ITU-T Recommendation G.992.1 [2] (reproduced in clause D.2).

4.2 Methods for configuring ADSL over ISDN

The methods for configuring ADSL over ISDN are described in ITU-T Recommendation G.992.1 [2]. Additional constraints on ADSL over ISDN operation are specified in clauses 4.2.1 and 4.2.2. annex C gives information to maintain backward compatibility with earlier version of the present document (the earlier version was based on ANSI T1.413 [9]).

4.2.1 EC ADSL over ISDN

EC ADSL over ISDN systems shall comply with the transmit spectral masks defined in clauses 4.2.1.1 and 4.2.1.2.

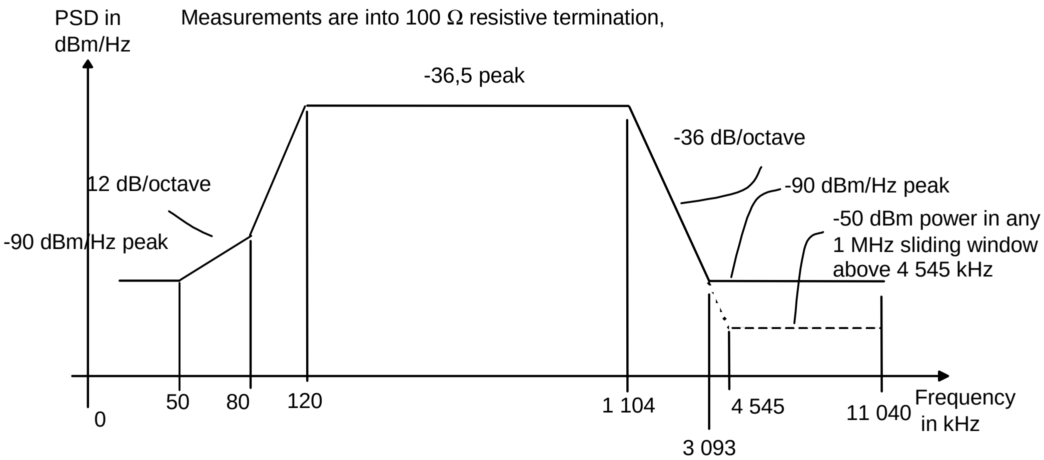
All PSD measurements made at the Line port of the ISDN splitter shall measure the spectral power into a resistive load having the same value as the design impedance for ADSL (R_V = 100 Ω).

The ISDN port of the ISDN splitter shall be terminated with the appropriate 2B1Q or 4B3T design impedance for ISDN-BA as defined in TS 102 080 [1].

It is intended that the degradation impact on the ISDN-BA line system performance be no more than 4,5 dB and 4 dB, for 2B1Q and 4B3T line codes respectively, at the insertion loss reference frequency.

4.2.1.1 Downstream transmit spectral mask

The ATU-C transmit PSD for EC ADSL over ISDN shall be as defined in figure 1 and in table 1.



NOTE: There is a discrepancy between the out-of-band power spectral density limits given in the present document and those given in a recently revised ETSI TS relating to ISDN-BA (TS 102 080 [1] V1.3.1). The out-of-band limits on ISDN-BA are more stringent than the limits on the ADSL system described in the present document. It is acknowledged that there is a need to make the documents consistent. This is for further study.

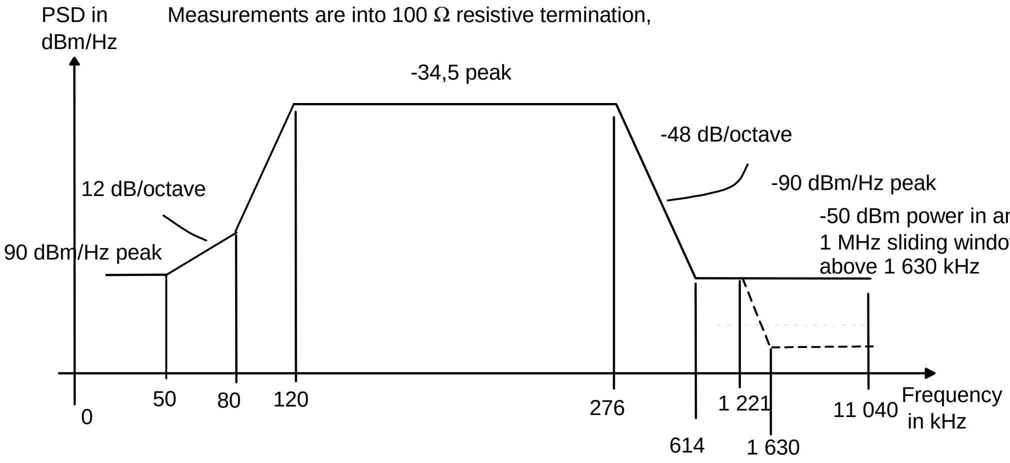
Figure 1: ATU-C transmitted PSD mask

Table 1: Line equations for the ATU-C Transmitted PSD mask

Frequency Band (kHz)	Equation for line (dBm/Hz)
0 ≤ f ≤ 50	-90
50 < f ≤ 80	-90 + 12 x $\log_2$(f/50)
80 < f ≤ 120	-81,8 + 77,4 x $\log_2$(f/80)
120 < f ≤ 1 104	-36,5
1 104 < f ≤ 3 093	-36,5 - 36 x $\log_2$(f/1 104)
3 093 < f ≤ 4 545	-90 peak, with maximum power in the [f, f + 1 MHz] window of (-36,5 - 36 x $\log_2$(f/1 104) + 60) dBm
4 545 < f ≤ 11 040	-90 peak, with maximum power in the [f, f + 1 MHz] window of -50 dBm

4.2.1.2 Upstream transmit spectral mask

The ATU-R transmit PSD for ADSL over ISDN shall be as defined in figure 2 and in table 2.



NOTE: There is a discrepancy between the out-of-band power spectral density limits given in the present document and those given in a recently revised ETSI TS relating to ISDN-BA (TS 102 080 [1] V1.3.1). The out-of-band limits on ISDN-BA are more stringent than the limits on the ADSL system described in the present document. It is acknowledged that there is a need to make the documents consistent. This is for further study.

Figure 2: ATU-R transmitted PSD mask

Table 2: Line equations for the ATU-R Transmitted PSD mask

Frequency band (kHz)	Equation for line (dBm/Hz)
$0 < f \leq 50$	-90
$50 < f \leq 80$	$-90 + 12 \times \log_2(f/50)$
$80 < f \leq 120$	$-81{,}8 + 77{,}4 \times \log_2(f/80)$
$120 < f \leq 276$	-34,5
$276 < f \leq 614$	$-34{,}5 - 48 \times \log_2(f/276)$
$614 < f \leq 1\,221$	-90
$1\,221 < f \leq 1\,630$	-90 peak, with maximum power in the [f, f + 1 MHz] window of $(-90 - 48 \times \log_2(f/1\,221) + 60)$ dBm
$1\,630 < f \leq 11\,040$	-90 peak, with maximum power in the[f, f + 1 MHz] window of -50 dBm

4.2.2 FDD ADSL over ISDN

FDD ADSL over ISDN systems shall comply with the transmit spectral masks defined in clauses 4.2.2.1 and 4.2.2.2.

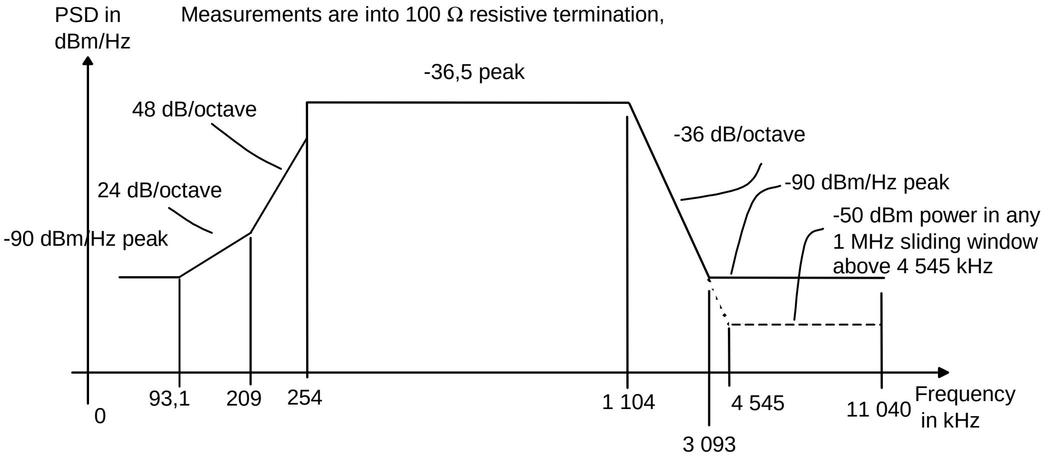
All PSD measurements made at the Line port of the ISDN splitter shall measure the spectral power into a resistive load having the same value as the design impedance for ADSL (R_V = 100 Ω).

The ISDN port of the ISDN splitter shall be terminated with the appropriate 2B1Q or 4B3T design impedance for ISDN-BA as defined in TS 102 080 [1].

It is intended that the degradation impact on the ISDN-BA line system performance be no more than 4,5 dB and 4 dB, for 2B1Q and 4B3T line codes respectively, at the insertion loss reference frequency.

4.2.2.1 Downstream transmit spectral mask

The ATU-C transmit PSD for FDD ADSL over ISDN shall be as defined in figure 3 and in table 3.



NOTE: There is a discrepancy between the out-of-band power spectral density limits given in the present document and those given in a recently revised ETSI TS relating to ISDN-BA (TS 102 080 [1] V1.3.1). The out-of-band limits on ISDN-BA are more stringent than the limits on the ADSL system described in the present document. It is acknowledged that there is a need to make the documents consistent. This is for further study.

Figure 3: ATU-C transmitted PSD mask

Table 3: Line equations for the ATU-C Transmitted PSD mask

Frequency Band (kHz)	Equation for line (dBm/Hz)
0 < f ≤ 93,1	-90
93,1 < f ≤ 209	$-90 + 24 \times \log_2(f/93,1)$
209 < f ≤ 254	$-62 + 48 \times \log_2(f/209)$
254 < f ≤ 1 104	-36,5
1 104 < f ≤ 3 093	$-36,5 - 36 \times \log_2(f/1\,104)$
3 093 < f ≤ 4 545	-90 peak, with maximum power in the [f, f + 1 MHz] window of $(-36,5 - 36 \times \log_2(f/1\,104) + 60)$ dBm
4 545 < f ≤ 11 040	-90 peak, with maximum power in the [f, f + 1 MHz] window of -50 dBm

4.2.2.2 Upstream transmit spectral mask

The ATU-R transmit PSD for ADSL over ISDN shall be as defined in clause 4.2.1.2.

4.3 Aggregate transmit power

The aggregate downstream power shall not exceed:

$$(-3,65 + 10 \times \log_{10}(ncdown))\ \text{dBm},$$

where ncdown is the number of downstream subcarriers used to carry bits (see clauses A.1.2.3.3 and B.1.3.2.2 of G.992.1 [2]). The aggregate upstream power shall not exceed:

$$(-1,65 + 10 \times \log_{10}(ncup))\ \text{dBm},$$

where ncup is the number of upstream subcarriers used to carry bits (see clauses A.2.4.3.3 and B.2.2.3.2 of ITU-T Recommendation G.992.1 [2]). Regardless of the number of subcarriers in use, the aggregate transmit power shall not exceed the transmit power given in table 4. The transmit power measurement shall measure the power into a resistive load having the same value as the design impedance for ADSL (R_V = 100 Ω).

Table 4: Maximum aggregate transmit power into 100 Ω

Signal type	Maximum Aggregate Transmit Power	Indicative number of carriers (see note)
EC ADSL over POTS down:	20,4 dBm	254
EC ADSL over POTS up:	12,5 dBm	26
FDD ADSL over POTS down:	19,9 dBm	227
FDD ADSL over POTS up:	12,5 dBm	27
EC ADSL over ISDN down:	19,9 dBm	227
EC ADSL over ISDN up:	13,3 dBm	31
FDD ADSL over ISDN down:	19,3 dBm	197
FDD ADSL over ISDN up:	13,3 dBm	31
NOTE: This column is only informative and gives the number of carriers that have to be transmitted at full power to reach the maximum aggregate power level. This information does not limit the effective number of carriers which may be used.		

NOTE: The values of the power spectral density limits shown in the document may not ensure to fulfil the requirements for the radiation power limits resulting of a national frequency management.

5 Transmission performance objectives and test methods

This clause defines the transmission performance objectives and laboratory test methods to stress ADSL transceivers in a manner representative of a high-penetration scenario in access networks. This high penetration approach enables operators to define deployment rules that apply to most operational situations. In individual operational cases, characterized by lower noise levels and/or insertion loss values, the ADSL system tested will perform better than under these test conditions.

The performance objectives described herein apply to both ADSL over POTS (see ITU-T Recommendation G.992.1 [2]) and ADSL over ISDN operations. The design impedance $\mathbf{R_V}$ is 100 Ω. In the context of this specification all spectra represent single-sided power spectral densities (PSDs).

5.1 Test procedures

This clause provides an unambiguous specification of the test set-up, the insertion path and definition of signal and noise levels. The tests focus on the noise margin when ADSL signals under test are attenuated by standard test-loops and interfered with by standard crosstalk noise or impulse noise. This noise margin indicates what increase of crosstalk noise or impulse noise level can be tolerated by the ADSL system under test before the bit error rate exceeds the design target.

NOTE: The interpretation of noise margin and the development of deployment rules based on minimum margin requirements under operational conditions are not the responsibility of transceiver manufacturers. Nevertheless, it is recommended that manufacturers provide Network Operators with simulation models that enable them to perform reliable predictions on transceiver behaviour under deviant insertion loss or crosstalk conditions. Different duplexing techniques may behave differently.

5.1.1 Test set-up definition

Figure 4 illustrates the functional description of the test set-up. It includes:

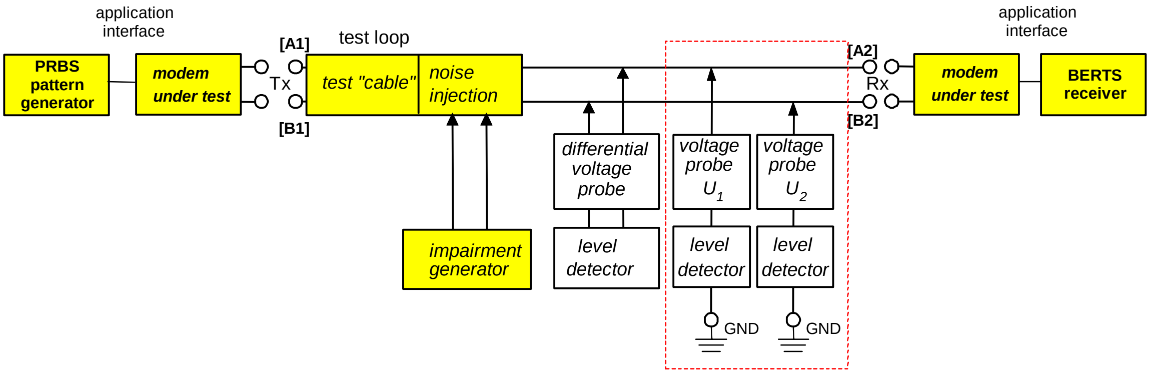
- the test loops, as specified in clause 5.2;
- an adding element to add impairments (a mix of random, impulsive and harmonic noise), as specified in clause 5.3;
- an impairment generator, as specified in clause 5.3, to generate both the differential mode and common mode impairment noise, which are input to the adding element;

- a high-impedance, well-balanced differential voltage probe (e.g. better than 60 dB across the whole band of the ADSL system under test), connected with level detectors such as a spectrum analyser or a true rms voltmeter;
- a high-impedance, well-balanced common mode voltage probe (e.g. better than 60 dB across the whole band of the ADSL system under test), connected with level detectors such as a spectrum analyser or a true rms voltmeter.

The two-port characteristics (insertion loss, impedance) of the test-loop, as specified in clause 5.2, are defined between port Tx (node pairs A1, B1) and port Rx (node pair A2, B2).

The noise injection network is specified in clause 5.1.2 , and is inserted between the test cable and the Rx port. This adding element is acting on both the differential and the common modes. The source present in this element is controlled by the impairment generator, as specified in clause 5.2.

The balance about earth, observed at port Tx, at port Rx and at the tips of the voltage probe, shall be at least 10 dB greater than the balance about earth of the transceiver under test. This is to ensure that the insertion of the impairment generator and monitor functions does not appreciably deteriorate the balance about earth of the transceiver under test.



NOTE 1: To allow test reproducibility, the testing equipment and the Termination Units (LTU and NTU) should refer to an artificial earth. If the Termination Units have no earth terminal, the test should be performed while the Termination Units are placed on a metal plate (of sufficient large size) connected to earth.
NOTE 2: When external splitters are required for the ADSL system under test (for POTS or ISDN signals), this splitter shall be included in or attached as an integral part of the modem under test.
NOTE 3: The functional description of ingress noise injection is not complete and requires further study.

Figure 4: Functional description of the set-up of the performance tests

The signal flow through the test set-up is from port Tx to port Rx, which means that measuring upstream and downstream performance requires an interchange of transceiver position and test "cable" ends.

The received signal level at port Rx is measured between nodes A2 and B2, when ports Tx and Rx are terminated with the ADSL transceivers under test. The impairment generator is switched off during this measurement.

Test Loop #0, as specified in clause 5.2, shall always be used to calibrate and verify the correct settings of generators G1-G7, as specified in clause 5.3.

The transmitted signal level at port Tx is measured between nodes A1 and B1 under the same conditions.

The impairment noise shall be a mix of random, impulsive and harmonic noise, as defined in clause 5.3.

5.1.2 Noise injection network

5.1.2.1 Differential mode injection

The noise injector for differential mode noise is a two-port network in nature, and may have additional ports connected to the impairment generator. The Norton equivalent circuit diagram is shown in figure 5. The current source I_x is controlled by the impairment generator. The parasitic shunt impedance Z_x shall have a value of $|Z_x| > 4\ k\Omega$ in the frequency range from 100 Hz to 2 MHz.

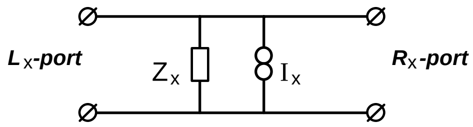


Figure 5: Norton equivalent circuit diagram for the differential mode noise injection

5.1.2.2 Common mode injection

This mode is for further study.

5.1.3 Signal and noise level definitions

The signal and noise levels are probed with a well-balanced differential voltage probe, and the differential impedance between the tips of the probe shall be higher than the shunt impedance of 100 kΩ in parallel with 10 pF. Figure 4 shows the probe position when measuring the Rx signal level at the LT or NT receiver. Measuring the Tx signal level requires the connection of the tips to node pair [A1, B1].

The various PSDs of signals and noises specified in the present document are defined at the Tx or Rx side of the set-up. The levels are defined when the set-up is terminated, as described above, with design impedance $\mathbf{R_V}$ or with ADSL transceivers under test.

Probing an rms-voltage U_{rms} [V] in this set-up, over the full signal band, means a power level of P [dBm] that equals:

$$P = 10 \times \log_{10} (U_{rms}^2/R_V \times 1\,000) \text{ [dBm]}$$

Probing an rms-voltage U_{rms} [V] in this set-up, within a small frequency band of Δf (in Hertz), corresponds to an average spectral density level of P [dBm/Hz] within that filtered band that equals:

$$P = 10 \times \log_{10} (U_{rms}^2/R_V \times 1\,000/\Delta f) \text{ [dBm/Hz]}$$

The bandwidth Δf identifies the noise bandwidth of the filter, and not the -3 dB bandwidth.

5.1.4 Noise levels calibration

5.1.4.1 Differential Mode Noise Calibration

The noise levels, as specified in clause 5.3, hold under calibration conditions in which no testloop is used (the "null-loop", or Loop 0) and while both sides of the differential mode noise injector are terminated with passive well-defined impedance, as illustrated in figure 6:

- The R_x side of the noise injector, is terminated during calibration by the design impedance $\mathbf{R_V}$ (= 100 Ω) of the modem under test.
- The Lx side of the noise injector is terminated during calibration by an impedance referred as $Z_{Line.}$ This impedance shall be **Rv** (= 100 Ω).

NOTE 1: It has been identified that a frequency dependent model for the impedance Z_{Line} would better represent the loop behaviour and would minimize the differences of noise power entering the modems between the calibration mode and the performance testing mode. The precise values are for further study.

NOTE 2: This proposed calibration method is in line with the crosstalk injection and calibration methods specified in ITU-T Recommendation G.996.1 (G.test) clause 5.1.2.1.

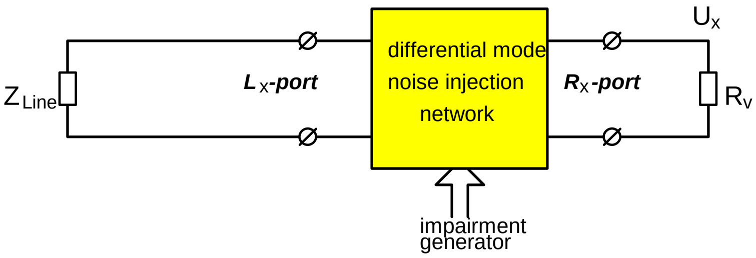


Figure 6: For which the noise level is defined, and applicable for calibration purposes

The noise generator source amplitude as fixed during calibration shall remain identical when the test configuration is switched to the performance testing mode.

During performance testing mode, the noise injector will be part of the circuit diagram in figure 4. In this configuration the termination impedances at both ports of the differential mode noise injector can be different from the values $\mathbf{R_v}$ used in figure 6 since the cable impedance and the actual impedances of the xDSL modem under test will be a slightly different from the design impedance $\mathbf{R_v}$. As a result the noise voltage $\mathbf{U'_x}$ during performance testing (as shown in figure 4) can be a slightly different from the noise voltage $\mathbf{U_x}$ during calibration (as shown in figure 6).

5.1.4.2 Common mode noise calibration

This calibration method is for further study.

5.1.5 Startup training procedure

The content of this clause is for further study.

5.2 Test loops

The purpose of the test loops shown in figure 7 is to stress ADSL transceivers under test in various ways, and in particular to test performance under quasi-realistic circumstances. Due to the requirement for ADSL transceivers to operate over the majority of metallic local lines without the requirement of any special conditioning a variety of test loops have been defined in clause 5.2.1.

5.2.1 Background information

The test loops in figure 7 are an artificial mixture of cable sections. A number of different loops have been used to capture a wide range of cable impedances, and to represent ripple in amplitude and phase characteristics of the testloop transmission functions:

- The test loops are characterized by their electrical lengths. The electrical length of each loop is defined as the insertion loss at a given test frequency, f_T. The total physical length, in meters, is also provided for information. In performance tests, the informative physical length can be used to establish a preliminary test loop. The length of the loop must then be adjusted, as specified in clause 5.2.3, to meet the normative electrical length requirements.

- The impedance characteristics of the test loops are such that they represent the impedances of a wide range of distribution cables that are commonly used in Europe. The purpose of a wide range of impedances is to stress the signal processing capabilities of the ADSL modem under test. This effect has been captured by defining some of the test loops with highly mismatched cable sections.

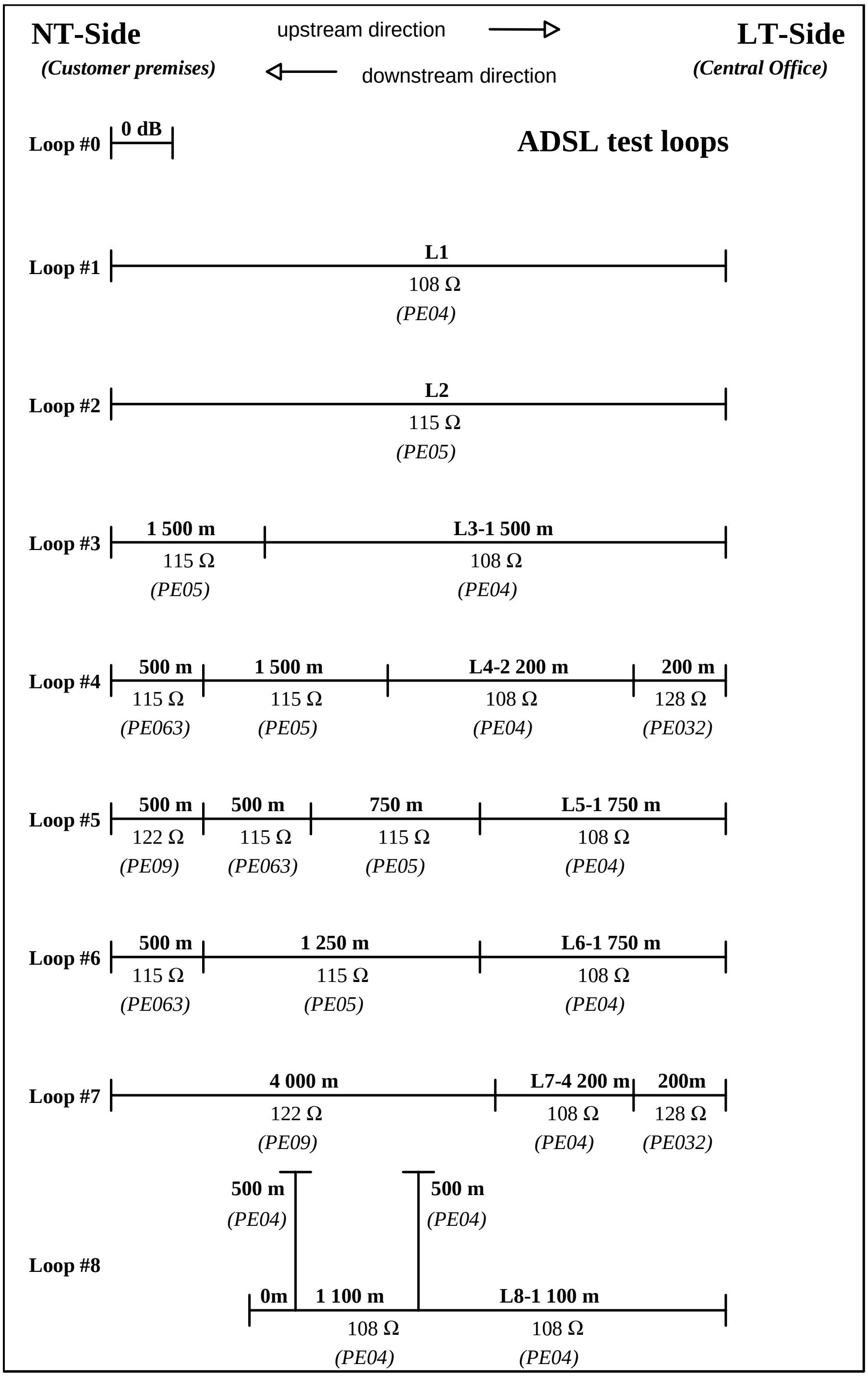
- One test loop includes bridged taps, which cause rapid variations in amplitude and phase characteristics of the cable transmission function. In some European access networks, installation practices have introduced bridge taps in the past. The presence of the bridge tap stresses the ADSL modem under test in a particular way.

- Loop #0 is a symbolic name for a loop with zero (or near zero) length, to prove that the ADSL transceiver under test can handle the potentially high signal levels when two transceivers are directly interconnected.

5.2.2 Testloop topology

The topology of the test loops is specified in figure 7. The values of line constants for the cables describing each individual section of the loops are specified in tables given in annex A.

The L parameters in figure 7 refer to the total physical length of each loop. Clause 5.5 specifies the normative electrical length for each loop as well as the informative physical length L and the test frequency f_T.



NOTE 1: Due to mismatches and bridged taps the total insertion loss of each test loop differs from the sum of the insertion loss of the parts.

NOTE 2: The impedances shown are for information only. They refer to the characteristic impedances of the test cables defined in annex A measured at 300 kHz.

NOTE 3: The values for L1 to L8 for performance objectives are given in clause 5.5.

Figure 7: ADSL test loop topology

5.2.3 Test loop accuracy

In the topology shown in figure 7, the different cable sections are specified by two-port cable models that represent real twisted pair cables. Cable simulators as well as real cables can be used for these test loops. The associated models and line constants are specified in annex A.

The characteristics of each test loop, including those with cascaded sections, shall approximate the models within a specified accuracy. This accuracy specification does not apply to the individual sections.

- The magnitude of the test-loop insertion loss shall approximate the insertion loss of the specified models within ±3 % on a dB scale, between $0,1 \times f_T$ and $6 \times f_T$.
- The magnitude of the test-loop characteristic impedance shall approximate the characteristic impedance of the specified models within ±7 % on a linear scale, between $0,1 \times f_T$ and $6 \times f_T$.
- The group delay of the test-loop shall approximate the group delay of the specified cascaded models within ±3 % on a linear scale, between $0,1 \times f_T$ and $6 \times f_T$.

The *electrical* lengths (insertion loss at specified test frequency), specified in clause 5.5, are normative. If the physical length of a test loop implementation is such that *electrical* length is out of specification, its total *physical* length shall be scaled accordingly to correct this error. This adjustment to the loop insertion loss by scaling of the physical length should also be used to correct for extra attenuation caused by the noise injection circuit.

5.3 Impairment generators

The noise the impairment generator injects into the test setup is frequency-dependent and dependent on the length and insertion loss of the test loop. The noise differs for downstream and upstream performance tests.

The definition of noise for ADSL performance tests is complex, and for the purposes of the present document it has been partitioned into smaller components, that can be specified more easily. These separate, and uncorrelated, impairment "generators" may therefore be isolated and summed to form the impairment generator for the ADSL system under test. The detailed specifications for the components of the noise model(s) are given in this clause, together with a brief explanation.

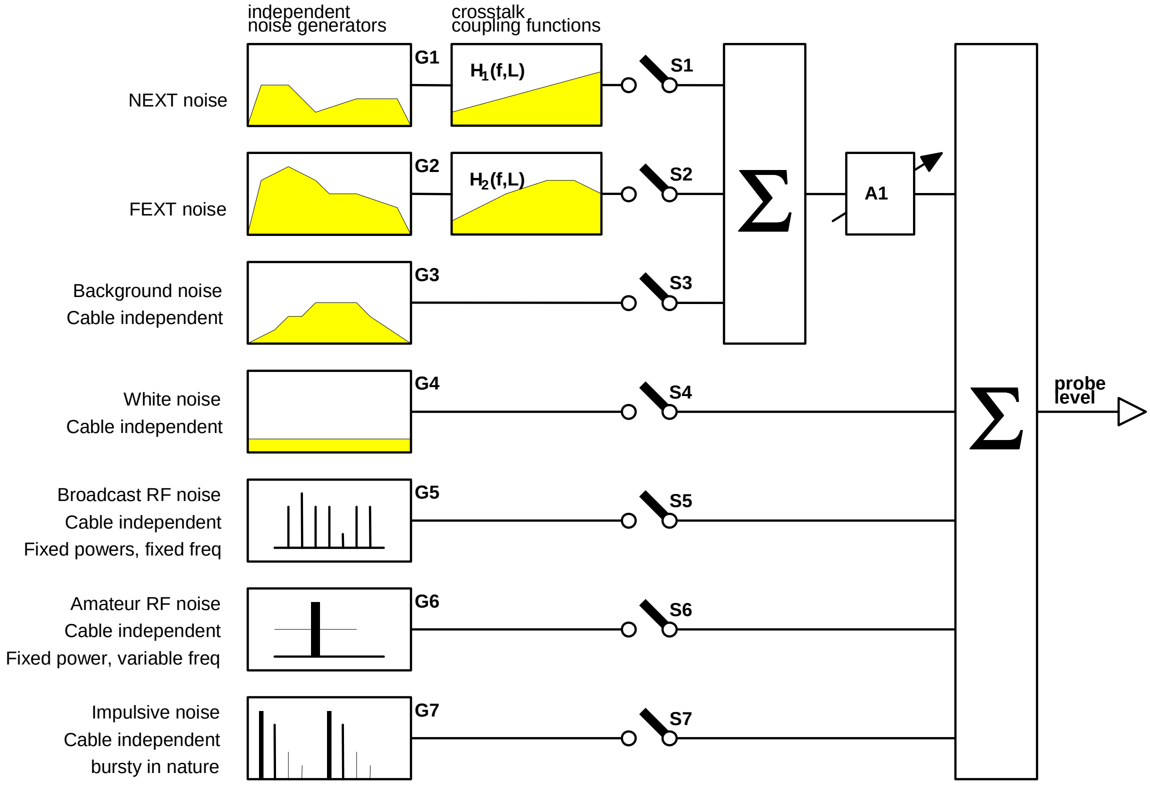
5.3.1 Functional description

Figure 8 defines a functional diagram of the composite impairment noise. It defines a functional description of the combined impairment noise, as it must be probed at the receiver input of the ADSL transceiver under test. This probing is defined in clause 5.1.3.

The functional diagram has the following elements:

- The seven impairment generators G1 to G7 generate noise as defined in clause 5.3.3.1 to 5.3.3.7. Their noise characteristics are independent off the test loops and bit-rates.
- The NEXT coupling function $H_1(f, L)$ models the loop length and frequency dependency of the NEXT impairment, as specified in clause 5.3.2. The NEXT coupling function is independent of the test loop topology, but dependent on the length of the test loop. The NEXT coupling function is defined in table 5.
- The FEXT coupling function $H_2(f, L)$ models the loop length and frequency dependency of the FEXT impairment, as specified in clause 5.3.2. The FEXT coupling function is independent of the test loop topology, but depends on the length of the test loop. The FEXT coupling function is defined in table 5.
- Switches S1-S7 determine whether or not a specific impairment generator contributes to the total impairment during a test.
- Amplifier A1 models the ability to increase the level of noise generators G1, G2 and G3 simultaneously to perform the noise margin tests as defined in clause 5.4.2. The gain of A1 (**x** dB) shall be frequency independent over the entire frequency band of the ADSL system under test. Unless otherwise specified, the gain of A1 is set to 0 dB.

The diagram in figure 8 is a conceptual diagram and does not specify the actual construction of the impairment generator. In a practical implementation of the test set-up, there is no need to give access to any of the internal signals of the diagram in figure 8. Furthermore, these functional blocks may be incorporated with the test loop and the adding element as one integrated construction.



NOTE 1: Generator G7 is the only generator symbolically shown in the time domain.
NOTE 2: The precise definition of impulse noise margin is for further study.
NOTE 3: Although generator G3 is inactive for ADSL tests, the noise construction in this figure is common to all xDSL specified by ETSI. For this reason, it is maintained in the diagram.
NOTE4: The primary purpose of generator G4 is to provide designers of noise generation equipment a reasonable noise floor to avoid over-design of their equipment.

Figure 8: Functional diagram of the composition of the impairment noise

This functional diagram will be used for impairment tests in downstream and upstream direction. Several scenarios have been identified for ADSL testing. These scenarios are intended to be representative of the impairments found in metallic access networks.

Each scenario (or noise model) results in a length-dependent and test loop-dependent PSD description of noise. Each noise model is subdivided into two parts: one to be injected at the LT-side, and another to be injected at the NT-side of the ADSL modem link under test. Therefore, seven individual impairment generators G1 to G7 can represent different values for each noise model they are used in. Specifically, G1 and G2 are dependent on which unit, LT or NT, is under test. Each test has its own impairment specification, as specified in clause 5.4. The overall impairment noise shall be characterized by the sum of the individual components as specified in the relevant clauses. This combined impairment noise is applied to the receiver under test, at either the LT (for upstream) or NT (for downstream) ends of the test-loop.

5.3.2 Cable cross-talk models

The purpose of the cable crosstalk models is to model both the length and frequency dependence of crosstalk measured in real cables. The crosstalk coupling functions, $H_1(f,L)$ and $H_2(f,L)$, are transfer functions that adjust the level of the noise generators in figure 8 when the test loop changes. The frequency and length dependency of these functions is in accordance with observations from real cables. The specification is based on the following constants, parameters and functions:

a) Variable **f** identifies the frequency in Hertz.

b) Constant $\mathbf{f_0}$ identifies a chosen reference frequency, which is 1 MHz in the present document.

c) Variable L identifies the physical length of the test loop in meters. This physical length is derived from the specified electrical length using the cable models in annex E and the cable characteristics of annex A. Values are summarized in table 19 through table 50 for each combination of payload bit rate, noise model and test loop. In the case of test loop 8, which has bridged taps, L is the physical length of the main path.

d) Constant $\mathbf{L_0}$ identifies a chosen reference length, which is 1 km in the present document.

e) The function $\mathbf{S_{T0}(f, L)}$ represents the frequency and length dependent amplitude of the transmission function of the actual test loop. This value equals $s_T = |s_{21}|$, where s_{21} is the transmission s-parameter of the loop normalized to 135 Ω. Annex E provides formulas to calculate this s-parameter.

f) Constant $\mathbf{K_{xn}}$ identifies an empirically-obtained number that scales the NEXT function $H_1(f, L)$. The resulting transfer function represents a power-summed crosstalk coupling of the NEXT as it was observed in a test cable. Although several disturbers and wire pairs were used in the derivation, the value of $\mathbf{K_{xn}}$ was scaled down as if it originates from a single disturber in a single wire pair.

g) Constant $\mathbf{K_{xf}}$ identifies an empirically-obtained number that scales the FEXT function $H_2(f, L)$ The resulting transfer function represents a power-summed crosstalk coupling of the FEXT as it was observed in a test cable. Although several disturbers and wire pairs were used in the derivation, the value of $\mathbf{K_{xn}}$ was scaled down as if it originates from a single disturber in a single wire pair.

The transfer functions in table 5 shall be used as cross-talk coupling functions in the impairment generator.

Table 5: Definition of the crosstalk coupling functions

$H_1(f, L) = K_{xn} \times (f/f_0)^{0,75} \times \sqrt{1 - \lvert s_{T0}(f, L)\rvert^4}$ $H_2(f, L) = K_{xf} \times (f/f_0) \times \sqrt{(L/L_0)} \times \lvert s_{T0}(f, L)\rvert$
$K_{xn} = 10^{(-50/20)} \approx 0{,}0032$, $f_0 = 1$ MHz $K_{xf} = 10^{(-45/20)} \approx 0{,}0056$, $L_0 = 1$ km $s_{T0}(f, L)$ = magnitude of test loop transmission function

5.3.3 Individual impairment generators

The noise produced by each impairment generator shall be uncorrelated with the noise produced by all other impairment generators, and uncorrelated with the xDSL system under test. The noise shall be random in nature and near Gaussian-distributed, as specified in clause 5.3.4.2.

5.3.3.1 Equivalent NEXT disturbance generator [G1.xx]

The NEXT noise generator represents the equivalent disturbance of all impairments that are identified as crosstalk noise from a predominantly near-end origin. This noise, filtered by the NEXT crosstalk coupling function of clause 5.3.2, represents the contributions of all NEXT to the composite impairment noise of the test.

The PSD of this noise generator is defined in clause 5.3.4.1. For testing upstream and downstream performance, different PSD profiles are to be used, as specified below:

G1.UP.# = X.LT.#

G1.DN.# = X.NT.#

The symbols in this expression, refer to the following:

- Symbol "#" is a placeholder for noise model "A", "B" , "C" or "D".
- Symbol "X.LT.#" and "X.NT.#" refers to the crosstalk profiles, as defined in clause 5.3.4.1.

This PSD is not related to the cable because the cable portion is modelled separately as part of the NEXT coupling function $H_1(f, L)$, as specified in clause 5.3.2.

5.3.3.2 Equivalent FEXT disturbance generator [G2.xx]

The FEXT noise generator represents the equivalent disturbance of all impairments that are identified as crosstalk noise from a predominantly far-end origin. This noise, filtered by the FEXT crosstalk coupling function of clause 5.3.2, represents the contributions of all FEXT to the composite impairment noise of the test.

The PSD of this noise generator is defined in clause 5.3.4.1. For testing upstream and downstream performance, different PSD profiles are to be used, as specified below:

G2.UP.# = X.NT.#

G2.DN.# = X.LT.#

The symbols in this expression, refer to the following:

- Symbol "#" is a placeholder for noise model "A", "B", "C" or "D".
- Symbol "X.LT.#" and "X.NT.#" refers to the crosstalk profiles, as defined in clause 5.3.4.1.

This PSD is not related to the cable because the cable portion is modelled separately as part of the FEXT coupling function $H_2(f, L)$, as specified in clause 5.3.2.

5.3.3.3 Background noise generator [G3]

The background noise generator is Inactive and set to zero.

5.3.3.4 White noise generator [G4]

The white noise generator has a fixed, frequency-independent value, and is set to -140 dBm/Hz into 135 Ω.

5.3.3.5 Broadcast RF noise generator [G5]

The broadcast RF noise generator represents the discrete-tone line interference caused by amplitude modulated broadcast transmissions in the SW, MW and LW bands, which ingress into the cable. These interference sources have more temporal stability than the amateur(ham) interference (see clause 5.3.3.6) because their carriers are not suppressed. Ingress causes differential mode as well as common mode interference.

The ingress noise signal for differentional mode impairment (or common mode impairment) is a superposition of random modulated carriers (AM). The total voltage $U(t)$ of this signal is defined as:

$$U(t) = \sum_k U_k \times cos(2\pi \cdot f_k \times t + \varphi_k) \times (1 + m \times \alpha_k(t))$$

The individual components of this ingress noise signal $U(t)$ are defined as follows:

- $\boldsymbol{U_k}$ - The voltage U_k of each individual carrier is specified in table 6 as power level P (dBm) into a resistive load R, equal to the design impedance R_V = 100 Ω. Note that spectrum analysers will detect levels that are slightly higher then the values specified in table 6 when their resolution bandwidths are set to 10 kHz or more, since they will detect the modulation power as well.

- $\boldsymbol{f_k}$ - The frequency f_k of each individual carrier is specified in table 6. The frequency values in table 6 do not represent actual broadcast frequencies but are chosen such that they cover the frequency range that is relevant for ADSL modems. Note that the harmonic relation between the carriers in table 6 is minimal.

- $\boldsymbol{\varphi_k}$ - The phase offset φ_k of each individual carrier shall have a random value that is uncorrelated with the phase offset of every other carrier in the ingress noise signal.

- $\boldsymbol{m}$ - The modulation depth m of each individually modulated carrier shall be m = 0,32, to enable a modulation index of at least 80 % during the peak levels of the modulation signal $m \times \alpha_k(t)$.

- $\boldsymbol{\alpha_k(t)}$ - The normalized modulation noise $\alpha_k(t)$ of each individually modulated carrier shall be random in nature, shall be Gaussian distributed in nature, shall have an RMS value of $\alpha_{rms} = 1$, shall have a crest factor of 2,5 or more, and shall be uncorrelated with the modulation noise of each other modulated carrier in the ingress noise signal.

- $\boldsymbol{\Delta b}$ - The modulation width Δb of each modulated carrier shall be at least 2 × 5 kHz. This is equivalent to creating $\alpha_k(t)$ from white noise, filtered by a low-pass filter having its cut-off frequency at $\Delta b/2$ = 5 kHz. This modulation width covers the full modulation band used by AM broadcast stations.

NOTE 1: The precise specification of the spectral shape requirements of the modulation signal is for further study.

The ingress noise generator may have two distinct outputs, one contributing to the differential mode impairment, and the other to the common mode impairment.

NOTE 2: The question of whether the differential mode and common mode signals are partly correlated or fully uncorrelated is **for further study**. The amount of correlation between differential and common mode signals is related to the frequency domain variations within a 10 kHz span of cable balance of real cables.

Table 6: Definition of the Broadcast RF frequencies and related power levels for differential and common mode ingress into 100 Ω

Frequency (kHz)	Power (dBm)
99	-70
207	-70
333	-70
387	-70
531	-70
603	-70
711	-70
801	-70
909	-70
981	-70
NOTE: The frequencies and power levels in table 6 are tentative and may be revised in the future.	

5.3.3.6 Amateur RF noise generator [G6]

The content of this clause is for further study.

5.3.3.7 Impulse noise generator [G7]

A test with this noise generator is required to prove the burst noise immunity of the ADSL transceiver. This immunity shall be demonstrated on short and long loops in the presence of noise that models crosstalk and RFI. Additional details are given in clause 5.4.

The noise shall consist of bursts of additive white Gaussian noise (AWGN) injected onto the line with sufficient power to ensure effective erasure of the data for the period of the burst, i.e. the bit error ratio during the burst should be approximately 0,5. The duration of the noise burst shall be no longer than 5μSec, and it shall be applied to the line at a frequency of once per second.

5.3.4 Profiles of the individual impairment generators

5.3.4.1 Frequency domain profiles of generator G1 and G2

Crosstalk noise represents all impairments that originate from systems connected to adjacent wire pairs that are coupled to the wires used by the ADSL systems. This noise spectrum varies with the electrical length of the test loop.

To simplify matters, the definition of crosstalk noise has been partitioned into smaller, more easily specified components. Noise generator G1 and G2 represent the "equivalent disturbance" of many disturbers in a real scenario, as if all disturbers were collocated at the ends of the test loop. This approach has isolated their definitions from the NEXT and FEXT coupling functions of the cable.

The following clauses specify the PSD profiles X.LT.# and X.NT.# that apply for the equivalent disturbers G1 and G2 (see figure 8) when testing ADSL over POTS and ADSL over ISDN systems. Both EC and FDD modes are addressed.

NOTE: The equivalent disturbers in these noise models are evaluated as a combination of several individual disturbers. When the equivalent disturbers were evaluated for the FDD versions of ADSL, the PSD values of one type of these disturbers have slightly changed compared to the values used for evaluating the EC version of ADSL.

The character "#" is used as a placeholder for the letters "A", "B" ,"C", and "D", which indicate the noise model.

Four noise models have been defined for ADSL tests:

- **Type "A" models** are intended to represent a ***high penetration scenario*** when the ADSL system under test is placed in a distribution cable (up to hundreds of wire pairs) that is filled with many other (potentially incompatible) transmission systems.

- **Type "B" models** are intended to represent a ***medium penetration scenario*** when the ADSL system under test is placed in a distribution cable (up to tens of wire pairs) that is filled with many other (potentially incompatible) transmission systems.

- **Type "C" models** are intended to represent a ***legacy scenario*** that accounts for the presence of systems such as ISDN-PRI (HDB3), in addition to the medium penetration scenario of model "B".

- **Type "D" models** are intended to represent a ***pure self-crosstalk scenario***, in which the cable is filled with ADSL only.

5.3.4.1.1 Frequency domain profiles for EC ADSL over POTS

The LT-profiles for EC ADSL over POTS systems are specified in table 7 and the NT-profiles in table 8. Each PSD profile specifies the maximum available spectral power of an equivalent disturber that represents a mix of disturbers. Since all originating disturbers may have source impedances that are different from the design impedance R_V of ADSL, the source impedance of this equivalent disturber has been made equal to the reference impedance R_N = 135 Ω used for characterizing cables properties. The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a logarithmic frequency scale and a linear dBm scale. These profiles shall be met for all frequencies between 1 kHz and 2 MHz.

Table 7: Break frequencies of the "X.LT.#" PSD masks for testing EC ADSL over POTS systems

X.LT.A [Hz]	135 Ω [dBm/Hz]
0	-20,0
15 k	-20,0
31 k	-21,5
63 k	-25,6
112 k	-25,7
204 k	-26,1
298 k	-26,6
420 k	-27,3
1,104 M	-27,3
4,5 M	-97,8
30 M	-97,8

X.LT.B [Hz]	135 Ω [dBm/Hz]
0	-25,6
15 k	-25,6
31 k	-27,0
63 k	-31,3
112 k	-31,3
204 k	-31,8
298 k	-32,5
420 k	-33,7
1,104 M	-33,7
4,5 M	-104,1
30 M	-104,1

X.LT.C [Hz]	135 Ω [dBm/Hz]
0	-25,6
15 k	-25,6
31 k	-27,0
63 k	-31,3
112 k	-31,3
204 k	-31,8
298 k	-32,5
420 k	-33,7
1,104 M	-33,7
1,85 M	-58,1
23 M	-104,1
30 M	-104,1

X.LT.D [Hz]	135 Ω [dBm/Hz]
0,0	-87,4
3,99 k	-87,4
4 k	-82,4
25,875k	-29,4
1,104 M	-29,4
3,093 M	-79,9
4,545 M	-99,9
30 M	-99,9

Table 8: Break frequencies of the "X.NT.#" PSD masks for testing EC ADSL over POTS systems

X.NT.A [Hz]	135 Ω [dBm/Hz]
0	-20,0
15 k	-20,0
22 k	-20,8
29 k	-20,8
61 k	-24,4
138 k	-24,5
153 k	-28,2
220 k	-28,9
315 k	-30,8
387 k	-34,6
461 k	-43,4
595 k	-62,5
755 k	-62,5
1,2 M	-75,3
2,6 M	-97,8
30 M	-97,8

X.NT.B [Hz]	135 Ω [dBm/Hz]
0	-25,6
15 k	-25,6
22 k	-26,6
29 k	-26,6
61 k	-30,3
138 k	-30,4
153 k	-33,2
220 k	-33,9
315 k	-35,5
387 k	-39,5
461 k	-48,3
605 k	-68,4
755 k	-68,4
1,2 M	-82,0
2,9 M	-104,1
30 M	-104,1

X.NT.C [Hz]	135 Ω [dBm/Hz]
0	-25,6
15 k	-25,6
22 k	-26,6
29 k	-26,6
61 k	-30,3
138 k	-30,4
153 k	-33,2
220 k	-33,9
315 k	-35,5
387 k	-39,5
469 k	-48,0
776 k	-45,5
1 030 k	-45,5
1,41 M	-48,9
1,8 M	-57,9
23 M	-104,1
30 M	-104,1

X.NT.D [Hz]	135 Ω [dBm/Hz]
0	-87,4
3,99 k	-87,4
4 k	-82,4
25,875 k	-27,4
138 k	-27,4
307 k	-79,9
1,221 M	-79,9
1,63 M	-99,9
30 M	-99,9

5.3.4.1.2 Frequency domain profiles for EC ADSL over ISDN

The LT-profiles for EC ADSL over ISDN systems are specified in table 9 and the NT-profiles in table 10. Each PSD profile represents a mix of disturbers. These profiles shall be met for all frequencies between 1 kHz and 2 MHz. The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a logarithmic frequency scale and a linear dBm scale.

Table 9: Break frequencies of the "X.LT.#" PSD masks for testing EC ADSL over ISDN systems

X.LT.A [Hz]	135 Ω [dBm/Hz]
0	-20,0
15 k	-20,0
30 k	-21,5
66 k	-27,7
130 k	-27,7
138 k	-25,9
204 k	-26,1
298 k	-26,6
420 k	-27,3
1,104 M	-27,3
4,5 M	-97,8
30	-97,8

X.LT.B [Hz]	135 Ω [dBm/Hz]
0	-25,6
15 k	-25,6
30 k	-27,2
66 k	-32,6
130 k	-32,7
138 k	-31,5
204 k	-31,8
298 k	-32,5
420 k	-33,7
1,104 M	-33,7
4,5 M	-104,1
30 M	-104,1

X.LT.C [Hz]	135 Ω [dBm/Hz]
0	-25,6
15 k	-25,6
30 k	-27,2
66 k	-32,6
130 k	-32,7
138 k	-31,5
204 k	-31,8
298 k	-32,5
420 k	-33,7
1,104 M	-33,7
1,85 M	-58,1
23 M	-104,1
30 M	-104,1

X.LT.D [Hz]	135 Ω [dBm/Hz]
0	-79,9
50 k	-79,9
80 k	-71,8
138 k	-29,4
1,104 M	-29,4
3,093 M	-79,9
4,545 M	-99,9
30 M	-99,9

Table 10: Break frequencies of the "X.NT.#" PSD masks for testing EC ADSL over ISDN systems

X.NT.A [Hz]	135 Ω [dBm/Hz]	X.NT.B [Hz]	135 Ω [dBm/Hz]	X.NT.C [Hz]	135 Ω [dBm/Hz]	X.NT.D [Hz]	135 Ω [dBm/Hz]
0	-20,0	0	-25,6	0	-25,6	0	-79,9
15 k	-20,0	15 k	-25,6	15 k	-25,6	50 k	-79,9
30 k	-21,6	30 k	-27,1	30 k	-27,1	80 k	-71,8
66 k	-27,7	65 k	-32,6	65 k	-32,6	138 k	-27,4
129 k	-27,7	129 k	-32,7	129 k	-32,7	276 k	-27,4
138 k	-24,5	138 k	-30,4	138 k	-30,4	614 k	-79,9
276 k	-24,9	276 k	-31,0	276 k	-31,0	1,221 M	-79,9
298 k	-28,8	296 k	-34,1	296 k	-34,1	1,63 M	-99,9
387 k	-34,6	381 k	-38,8	381 k	-38,8	30 M	-99,9
500 k	-48,6	461 k	-48,3	469 k	-48,0		
595 k	-62,5	605 k	-68,4	776 k	-45,5		
755 k	-62,5	755 k	-68,4	1,030 M	-45,5		
1,2 M	-75,3	1,2 M	-82,0	1,410 M	-48,9		
2,6 M	-97,8	2,9 M	-104,1	1,8 M	-57,9		
30 M	-97,8	30 M	-104,1	23 M	-104,1		
				30 M	-104,1		

5.3.4.1.3 Frequency domain profiles for FDD ADSL over POTS

The LT-profiles for FDD ADSL over POTS systems are specified in table 11 and the NT-profiles in table 12. Each PSD profile represents a mix of disturbers. These profiles shall be met for all frequencies between 1 kHz and 2 MHz. The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a logarithmic frequency scale and a linear dBm scale.

Table 11: Break frequencies of the "X.LT.#" PSD masks for testing FDD ADSL over POTS systems

X.LT.A [Hz]	135 Ω [dBm/Hz]	X.LT.B [Hz]	135 Ω [dBm/Hz]	X.LT.C [Hz]	135 Ω [dBm/Hz]	X.LT.D [Hz]	135 Ω [dBm/Hz]
1	-20,1	1	-25,7	1	-25,8	1	-87,4
15 k	-20	15 k	-25,6	15 k	-25,6	3,99 k	-87,4
30 k	-21,6	30 k	-27,1	30 k	-27,2	4 k	-82,4
45 k	-24,1	45 k	-29,6	45 k	-29,7	80 k	-62,4
64 k	-27,6	65 k	-32,6	63 k	-32,6	137,99 k	-34,1
137,99 k	-27,7	137,99 k	-32,8	137 k	-32,8	138 k	-29,9
138 k	-26,1	138 k	-31,7	139 k	-31,7	1 104 k	-29,9
277 k	-26,8	272 k	-32,5	294 k	-32,7	3 093 k	-79,9
407 k	-27,8	414 k	-34,2	417 k	-34,2	4 545 k	-99,9
1,106 M	-27,8	1,103 M	-34,2	1 110 k	-34,2	30 M	-99,9
4,544 M	-96,2	4,360 M	-101,6	2 160 k	-66,1		
30 M	-96,2	30 M	-101,6	2 400 k	-63,6		
				2 550 k	-63,8		
				20 M	-101,6		
				30 M	-101,6		

Table 12: Break frequencies of the "X.NT.#" PSD masks for testing FDD ADSL over POTS systems

X.NT.A [Hz]	135 Ω [dBm/Hz]
1	-20,0
15 k	-20,0
24 k	-20,9
30 k	-21,0
45 k	-23,0
60 k	-24,7
138 k	-24,9
151 k	-28,0
207 k	-28,7
300 k	-30,3
358 k	-32,8
407 k	-36,7
500 k	-48,6
594 k	-62,3
755 k	-62,3
1 059 k	-73,7
1 221 k	-75,5
1 400 k	-77,9
2 532 k	-96,2
30 M	-96,2

X.NT.B [Hz]	135 Ω [dBm/Hz]
1	-25,8
15 k	-25,6
24 k	-26,5
30 k	-26,8
61 k	-30,5
138 k	-30,8
149 k	-33,0
200 k	-33,5
308 k	-35,2
375 k	-38,5
456 k	-46,9
605 k	-68,4
755 k	-68,4
980 k	-77,3
1 128 k	-80,8
1 402 k	-83,7
2 570 k	-101,6
30 M	-101,6

X.NT.C [Hz]	135 Ω [dBm/Hz]
1	-25,8
2 k	-25,8
15 k	-25,6
22 k	-26,4
30 k	-26,8
45 k	-28,8
60 k	-30,5
138 k	-30,7
150 k	-33,0
206 k	-33,6
338 k	-35,7
477 k	-47,8
788 k	-45,4
1 064 k	-45,5
1 500 k	-50,1
1 800 k	-58,6
20 M	-101,6
30 M	-101,6

X.NT.D [Hz]	135 Ω [dBm/Hz]
1	-87,4
3,99 k	-87,4
4 k	-82,4
25,875 k	-27,9
138 k	-27,9
307 k	-79,9
1 221 k	-79,9
1 630 k	-99,9
30 M	-99,9

5.3.4.1.4 Frequency domain profiles for FDD ADSL over ISDN

The LT-profiles for FDD ADSL over ISDN systems are specified in table 13 and the NT-profiles in table 14. Each PSD profile represents a mix of disturbers. These profiles shall be met for all frequencies between 1 kHz and 2 MHz. The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a logarithmic frequency scale and a linear dBm scale.

Table 13: Break frequencies of the "X.LT.#" PSD masks for testing FDD ADSL over ISDN systems

X.LT.A [Hz]	135 Ω [dBm/Hz]
1	-20,1
14 k	-20
30 k	-21,5
45 k	-24,1
64 k	-27,7
105 k	-27,6
204 k	-28,7
253 k	-29,4
255 k	-26,7
412 k	-27,8
1 104 k	-27,8
4 543 k	-96,2
30 M	-96,2

X.LT.B [Hz]	135 Ω [dBm/Hz]
1	-25,8
2 k	-25,8
15 k	-25,6
30 k	-27,1
45 k	-29,6
66 k	-32,6
106 k	-32,6
200 k	-33,6
253 k	-34,3
254 k	-32,5
303 k	-32,9
417 k	-34,2
1 104 k	-34,2
4 439 k	-101,6
30 M	-101,6

X.LT.C [Hz]	135 Ω [dBm/Hz]
1	-25,7
15 k	-25,6
30 k	-27,2
45 k	-29,6
62 k	-32,6
107 k	-32,6
203 k	-33,6
253,8 k	-34,3
254 k	-32,5
300 k	-32,8
409 k	-34,2
1 104 k	-34,2
1 703 k	-53,6
2 162 k	-66,2
2 387 k	-63,7
2 520 k	-63,6
2 677 k	-65,5
20 M	-101,6
30 M	-101,6

X.LT.D [Hz]	135 Ω [dBm/Hz]
1	-79,9
93,1 k	-79,9
209 k	-51,9
253,99 k	-38,4
254 k	-29,9
1 104 k	-29,9
3 093 k	-79,9
4 545 k	-99,9
30 M	-99,9

Table 14: Break frequencies of the "X.NT.#" PSD masks for testing FDD ADSL over ISDN systems

X.NT.A [Hz]	135 Ω [dBm/Hz]
1	-20,1
15 k	-20
30 k	-21,5
45 k	-24,1
65 k	-27,6
111 k	-27,7
120 k	-24,8
275 k	-25,3
300 k	-29,1
403 k	-36
500 k	-48,6
614 k	-64,8
630 k	-64,8
651 k	-62,3
755 k	-62,4
1 023 k	-72,7
1 220 k	-75,5
1 400 k	-77,9
2 590 k	-96,2
30 M	-96,2

X.NT.B [Hz]	135 Ω [dBm/Hz]
1	-25,8
2 k	-25,8
15 k	-25,6
30 k	-27,1
44 k	-29,6
64 k	-32,6
114 k	-32,6
120 k	-30,7
277 k	-31,4
305 k	-34,9
389 k	-39,3
500 k	-53,6
620 k	-70,1
633 k	-70,1
650 k	-68,2
758 k	-68,5
1 071 k	-79,9
1 222 k	-81,6
1 398 k	-83,7
2 479 k	-101,6
30 M	-101,6

X.NT.C [Hz]	135 Ω [dBm/Hz]
1	-25,6
15 k	-25,6
30 k	-27,2
45 k	-29,6
62 k	-32,6
114 k	-32,7
120 k	-30,7
200 k	-31,0
276 k	-31,4
300 k	-34,6
377 k	-38,7
470 k	-47,8
802 k	-45,4
1 024 k	-45,6
1 309 k	-47,8
1 587 k	-52,3
1 900 k	-63,0
2 011 k	-76,8
2 283 k	-63,7
2 492 k	-63,7
2 716 k	-66,1
20 M	-101,6
30 M	-101,6

X.NT.D [Hz]	135 Ω [dBm/Hz]
1	-79,9
50 k	-79,9
80 k	-71,8
120 k	-27,9
276 k	-27,9
614 k	-79,9
1 221 k	-79,9
1 630 k	-99,9
30 M	-99,9

5.3.4.2 Time domain profiles of generator G1-G4

The noise, as specified in the frequency domain in clause 5.3.3.1 to 5.3.3.4, shall be random in nature and near Gaussian distributed. This means that the amplitude distribution function of the combined impairment noise injected at the adding element (see figure 4) shall lie between the two boundaries illustrated in figure 9 and defined in table 15.

The amplitude distribution function F(a) of noise u(t) is the fraction of the time that the absolute value of u(t) exceeds the value "a". From this definition, it can be concluded that F(0) = 1 and that F(a) monotonically decreases up to the point where "a" equals the peak value of the signal. From there on, F(a) vanishes:

$$F(a) = 0 \text{ , for } a \geq \left| u_{peak} \right| .$$

The boundaries on the amplitude distribution ensure that the noise is characterized by peak values that are occasionally significantly higher than the rms-value of that noise (up to 5 times the rms-value).

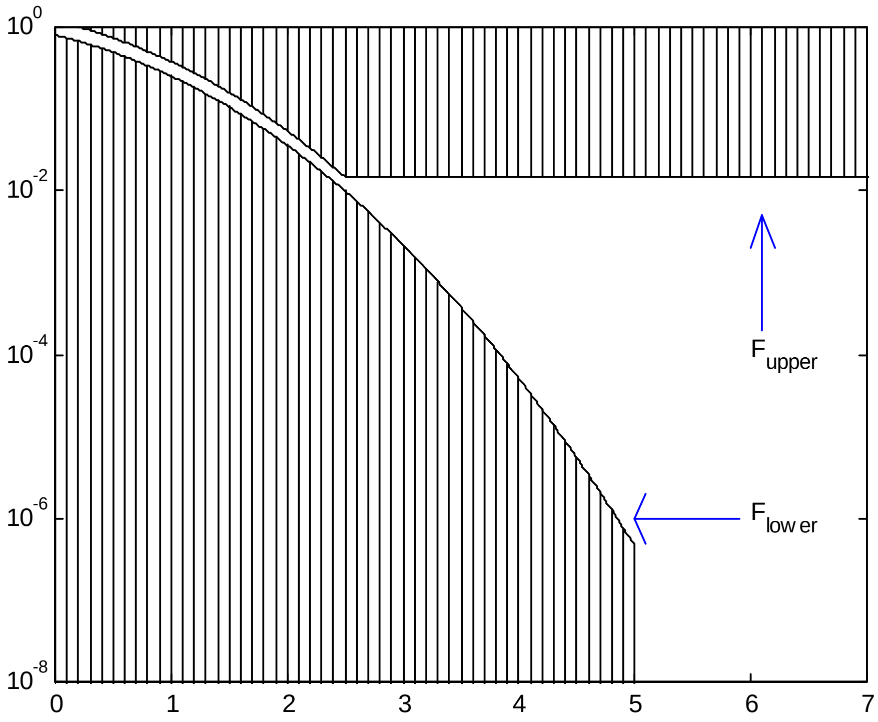


Figure 9: Mask for the Amplitude Distribution Function: the non-shaded area is the allowed region; the boundaries of the mask are specified in table 15

Table 15: Upper and lower boundaries of the amplitude distribution function of the noise

Boundary (σ = rms value of noise)	interval
$F_{lower}(a) = (1 - \varepsilon) \cdot \{1 - erf((a/\sigma)/\sqrt{2})\}$	$0 \leq a/\sigma < CF$
$F_{lower}(a) = 0$	$CF \leq a/\sigma < \infty$
$F_{upper}(a) = (1 + \varepsilon) \cdot \{1 - erf((a/\sigma)/\sqrt{2})\}$	$0 \leq a/\sigma < A$
$F_{upper}(a) = (1 + \varepsilon) \cdot \{1 - erf(A/\sqrt{2})\}$	$A \leq a/\sigma < \infty$

parameter	value
crest factor	CF = 5
Gaussian gap	ε = 0,1
	A = CF/2 = 2,5

The meaning of the parameters in table 15 is as follows:

- CF denotes the minimum crest factor of the noise. Crest factor is defined as the ratio between the absolute peak value and rms value ($CF = |u_{peak}|/u_{rms}$).
- ε denotes the Gaussian gap that indicates how closely the near Gaussian noise approximates true Gaussian noise.
- "A" denotes the point beyond which the upper limit is alleviated to allow the use of noise signals of practical repetition length.

5.4 Transmission Performance tests

5.4.1 Bit error ratio requirements

The ADSL system under test shall operate with a noise margin of at least +6 dB and a long-term bit error ratio of < 1 in 10^7 when operated over any of the test loops with the noise models and test conditions as specified in this clause. The noise margin is measured using the method described in clause 5.4.2.1.

The measurement period shall be at least $(N \times 10^7)/R$, where N = 100 and R is the bit rate in the direction being tested. A long term performance test shall be performed for a period of not less than 24 hours to ensure long-term temporal stability (see clause 5.4.3).

5.4.2 Measuring noise margin

Before start-up of the ADSL modem under test, the level and shape of injected noise are adjusted, and their level is probed at port Rx to meet the impairment level specification in clause 5.3. This relative level is referred to as 0 dB. The transceiver link is subsequently activated, and the bit error ratio of the link is monitored.

5.4.2.1 Measuring crosstalk noise margin

To measure the crosstalk noise margin, the crosstalk noise level **x** is adjusted in steps of **Δx** dB until the bit error ratio (BER) is higher than 10^{-7}. The adjustment to the noise level shall be equivalent to adjusting the gain of amplifier A1 in figure 8, equally over the full frequency band of the ADSL system under test. The crosstalk noise margin is defined as the highest increase in noise level, relative to the 0dB level, that has BER no higher than 10^{-7}.

The noise margins shall be measured for upstream as well as downstream transmission for all the test loop defined in clause 5.2 except loop #0, the zero length loop. To verify that ADSL systems under test meet the 6dB crosstalk noise margin requirement it is sufficient to verify that the BER is at least 10^{-7} when the noise level is increased by 6dB, in steps of 1dB, relative to the 0dB reference level.

5.4.2.2 Measuring impulse noise margin

The content of this clause is for further study.

5.4.3 Test sequences

Compliance with the performance objectives in clause 5.5 shall be demonstrated by means of a mandatory subset of all possible performance tests described in the present document. Table 16 specifies these mandatory conformance tests for downstream transmission, and table 17 specifies the test for upstream transmission.

Each symbolic name in this table refers to a specific noise model, as defined in clause 5.3.4.1. The injection of the impairment noise shall be at the receiver side of the ADSL transmission direction under test. The test sequences apply to ADSL over POTS and ADSL over ISDN variants.

Two groups of conformance tests are defined. In group 1 tests only crosstalk noise is injected, while in group 2 tests a combination of crosstalk noise and ingress noise are injected. Group 2 is associated with a modified (shorter) reach requirement.

Table 16: Testmatrix for downstream conformance testing, defining the composition of testloops and noise models that are to be used for various downstream bitrates

group	Bitrate kb/s	Test loops	G1.DN.# (#=model)	G2.DN.# (#=model)	G3	G4	G5	G6	G7	reach	number of tests
1	**512**	0,1 8	A,B,C,D	A,B,C,D	-	×	-	-	-	R1.d	36
	1 024	0,1 8	A,B,C,D	A,B,C,D	-	×	-	-	-	R1.d	36
	2 048	0,1 8	A,B,C,D	A,B,C,D	-	×	-	-	-	R1.d	36
	6 144	0,1 8	A,B,C,D	A,B,C,D	-	×	-	-	-	R1.d	36
2	**512**	1,7	A,B	A,B	-	×	×	-	-	R2.d	4
	1 024	1,7	A,B	A,B	-	×	×	-	-	R2.d	4
	2 048	1,7	A,B	A,B	-	×	×	-	-	R2.d	4
	6 144	1,7	A,B	A,B	-	×	×	-	-	R2.d	4

1-8 means test loop one through eight

× means that the equivalent noise generator is activated

- means absent or not activated

R1.d means the downstream performance objectives, specified in clause 5.5

R2.d means the (modified) downstream performance objectives, specified in clause 5.5

Note that the different variants of ADSL use different noise models and performance objectives.

Table 17: Testmatrix for upstream conformance testing, defining the composition of testloops and noise models that are to be used for various upstream bitrates

group	Bitrate kb/s	Test loops	G1.UP.# (#=model)	G2.UP.# (#=model)	G3	G4	G5	G6	G7	reach	number of tests
1	**64**	0,1 8	A,B,C,D	A,B,C,D	-	×	-	-	-	R1.u	36
	256	0,1 8	A,B,C,D	A,B,C,D	-	×	-	-	-	R1.u	36
	640	0,1 8	A,B,C,D	A,B,C,D	-	×	-	-	-	R1.u	36
2	**64**	1,7	A,B	A,B	-	×	×	-	-	R2.u	4
	256	1,7	A,B	A,B	-	×	×	-	-	R2.u	4
	640	1,7	A,B	A,B	-	×	×	-	-	R2.u	4

1-8 means test loop one through eight

× means that the equivalent noise generator is activated

\- means absent or not activated

R1.u means the upstream performance objectives, specified in clause 5.5

R2.u means the (modified) upstream performance objectives, specified in clause 5.5

Note that the different variants of ADSL use different noise models and performance objectives.

5.4.4 Micro-interruptions

A micro-interruption is a temporary line interruption due to external mechanical action on the copper wires constituting the transmission path, for example, at a cable splice. Splices can be hand-made wire-to-wire junctions, and during cable life oxidation phenomena and mechanical vibrations can induce micro-interruptions at these critical points.

The effect of a micro-interruption on the transmission system can be a failure of the digital transmission link, together with a failure of the power feeding (if provided) for the duration of the micro-interruption.

The objective is that in the presence of a micro-interruption of specified maximum length, the ADSL transceiver should not reset, and the system should resume normal reception and transmission.

The transceiver shall not be reset by a micro-interruption event of duration t = 10 ms, which shall occur at an event frequency of 0,2 Hz.

NOTE 1: Caution related to the duration of test.

NOTE 2: After missing RX signal a few times for 10 ms (i.e. 40 symbols, and several kbit) the ADSL modem will report severely errored seconds, at a rhythm of 1 every 5 seconds. Under these circumstances the modem might be asked to retrain by higher layers, although the modem has not lost synchronization and although there is no need for the modem to retrain in this particular test.

5.5 Performance objectives

The performance objectives, R1.d and R1.u, for each test loop for ADSL transmission systems are specified in tables19 through 50. There are different objectives for EC ADSL over POTS, EC ADSL over ISDN, FDD ADSL over POTS, and FDD ADSL over ISDN. The performance objectives R2.d and R2.u are for further study.

For each test case in the performance objective tables, the specified electrical length Y (insertion loss at the specified test frequency) is normative. The physical lengths L are given for information only. If the electrical length of a test loop is out of specification when the informative physical length is used, then the total physical length of the loop shall be adjusted as specified in clause 5.2.3.

The length is chosen to be a typical maximum loop length for which the ADSL transceiver under test can support the specified bit rate at the target bit error rate. This value is bit rate dependent; the higher the payload bit rate, the lower is the insertion loss that can be handled in practice.

In the context of the performance objectives in this clause, payload data rate means net data rate as specified in clauses 6.2 and 6.3 of ITU-T Recommendation G.992.1 [2]. For ATM transfer, the ATM overhead is included in the net data rate.

5.5.1 Performance objectives for EC ADSL over ISDN

Tables 19 through 26 provide performance objectives for EC ADSL over ISDN with noise models A through D. These performance objectives shall be met while maintaining a bit error ratio of 10^{-7} or lower. Systems should meet these objectives when configured as specified in table 18.

Table 18: Modem configuration parameters for performance verification

Parameter	Value
Path	Slow
Interleaver	Enabled
Latency	High
Trellis	Enabled (see note)
Noise margin	6dB
NOTE: Although trellis coding is an optional feature in G.992.1 [2], trellis coding can be used to meet the performance objectives in tables 19 through 50.	

Table 19: Reach requirements for EC ADSL over ISDN downstream with noise model A

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 20: Reach requirements for EC ADSL over ISDN upstream with noise model A

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 21: Reach requirements for EC ADSL over ISDN downstream with noise model B

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 22: Reach requirements for EC ADSL over ISDN upstream with noise model B

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 23: Reach requirements for EC ADSL over ISDN downstream with noise model C

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 24: Reach requirements for EC ADSL over ISDN upstream with noise model C

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 25: Reach requirements for EC ADSL over ISDN downstream with noise model D

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 26: Reach requirements for EC ADSL over ISDN upstream with noise model D

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

5.5.2 Performance objectives for EC ADSL over POTS

Tables 27 through 34 provide performance objectives for EC ADSL over POTS with noise models A through D. These performance objectives shall be met while maintaining a bit error ratio of 10^{-7} or lower. Systems should meet these objectives when configured as specified in table 18.

Table 27: Reach requirements for EC ADSL over POTS downstream with noise model A

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 28: Reach requirements for EC ADSL over POTS upstream with noise model A

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 29: Reach requirements for EC ADSL over POTS downstream with noise model B

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 30: Reach requirements for EC ADSL over POTS upstream with noise model B

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 31: Reach requirements for EC ADSL over POTS downstream with noise model C

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 32: Reach requirements for EC ADSL over POTS upstream with noise model C

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 33: Reach requirements for EC ADSL over POTS downstream with noise model D

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 34: Reach requirements for EC ADSL over POTS upstream with noise model D

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

5.5.3 Performance objectives for FDD ADSL over ISDN

Tables 35 through 42 provide performance objectives for FDD ADSL over ISDN with noise models A through D. These performance objectives shall be met while maintaining a bit error ratio of 10^{-7} or lower. Systems should meet these objectives when configured as specified in table 18.

Table 35: Reach requirements for FDD ADSL over ISDN downstream with noise model A

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 36: Reach requirements for FDD ADSL over ISDN upstream with noise model A

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 37: Reach requirements for FDD ADSL over ISDN downstream with noise model B

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 38: Reach requirements for FDD ADSL over ISDN upstream with noise model B

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 39: Reach requirements for FDD ADSL over ISDN downstream with noise model C

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 40: Reach requirements for FDD ADSL over ISDN upstream with noise model C

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 41: Reach requirements for FDD ADSL over ISDN downstream with noise model D

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 42: Reach requirements for FDD ADSL over ISDN upstream with noise model D

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

5.5.4 Performance objectives for FDD ADSL over POTS

Tables 43 through 50 provide performance objectives for FDD ADSL over POTS with noise models A through D. These performance objectives shall be met while maintaining a bit error ratio of 10^{-7} or lower. Systems should meet these objectives when configured as specified in table 18.

Table 43: Reach requirements for FDD ADSL over POTS downstream with noise model A

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 44: Reach requirements for FDD ADSL over POTS upstream with noise model A

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 45: Reach requirements for FDD ADSL over POTS downstream with noise model B

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 46: Reach requirements for FDD ADSL over POTS upstream with noise model B

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 47: Reach requirements for FDD ADSL over POTS downstream with noise model C

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 48: Reach requirements for FDD ADSL over POTS upstream with noise model C

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

Table 49: Reach requirements for FDD ADSL over POTS downstream with noise model D

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
512	300								
768	300								
1 024	300								
1 544	300								
2 048	300								
3 072	300								
4 096	300								
5 120	300								
6 144	300								
NOTE: The content of this table is for further study.									

Table 50: Reach requirements for FDD ADSL over POTS upstream with noise model D

Payload Bitrate [kb/s]	f_T [kHz]	Loop #1 Y [dB]	Loop #2 Y [dB]	Loop #3 Y [dB]	Loop #4 Y [dB]	Loop #5 Y [dB]	Loop #6 Y [dB]	Loop #7 Y [dB]	Loop #8 Y [dB]
64	300								
128	300								
256	300								
384	300								
512	300								
640	300								
NOTE: The content of this table is for further study.									

6 ADSL splitter

The main purpose of the splitter filter is to separate the transmission of tele band signals (originated from POTS or ISDN-BA), and ADSL band signals (originated from ADSL). A second purpose is to isolate poorly balanced tele band equipment from the line at "ADSL band" frequencies, in order to prevent unnecessary egress (and ingress) from ADSL signals.

Insertion of a splitter filter in existing POTS or ISDN-BA lines shall have only a low impact on the performance of existing services. An excellent splitter filter is therefore near transparent for frequencies in a specified pass band. Near transparency between two ports means that (1) the insertion loss in the pass band is close to 0 dB and that (2) the input impedance at one port is close to the load impedance at the other port over a specified range of load impedances.

The splitter filter may be implemented as an independent unit, separately from the ADSL transceiver, or may be integrated with the ADSL termination unit.

The splitter shall meet the requirements of this clause with all ADSL transceiver impedances that are tolerated by the return loss specification.

Designs shall take into careful account the relevant national specifications. In the absence of national specifications the narrowband requirements of EN 300 001 [4] and TBR 021 [5] shall be met for POTS, and of TS 102 080 [1] for ISDN-BA.

NOTE: The splitters designed according to the present document are expected to be adequate under a wide range of operational conditions. The issue of general interoperability between ISDN equipment and splitters is for further study.

6.1 Functional diagram

A splitter filter is required at both ends of the line which carries ADSL signals because it is intended that existing baseband services are to remain unaffected by the presence of higher frequency ADSL signals on the same wire-pair. The functional diagram of this combination is given in figure 10.

The following is advised to maintain minimum guaranteed performance:

- The end-to-end insertion loss from port "Naa" to "Nba" do not exceed the maximum values as specified for the testloops in clause 5.5.
- The length of cable section Laa and Lba in the presence of ISDN transmission according to TS 102 080 [1], annex B (4B3T) should not exceed the values specified in table 51 in order not to influence the ISDN transmission. The values in the presence of ISDN 2B1Q are for further study.
- The length (insertion loss) of Lat + Lbt + L0 - 4 dB for ISDN 4B3T and 4,5 dB for ISDN 2B1Q should not exceed the maximum reach for the reach requirements in clause 6 of TS 102 080 [1] (the reduced reach is to allow for the presence of the splitters and the parallel ADSL transmission).

Table 51: Recommended limits on cable section lengths for 4B3T ISDN

Cable section	advised maximum length (see note 4)	Termination at the end of the cable section
Laa; Lba	200 (see note 1)	NT, LT, or open loop
Laa; Lba	150 (see note 2)	NT, LT, or open loop
Laa; Lba	50 (see note 3)	NT, LT, or open loop
NOTE 1: Tests a to g in TS 102 080 [1] and the length of the ADSL cable section (Laa or Lba) at the other port << 150 m.		
NOTE 2: Tests a to g in TS 102 080 [1] and the length of the ADSL cable section (Laa or Lba) at the other port = 150 m.		
NOTE 3: Tests h, i in TS 102 080 [1] and the length of the ADSL cable section (Laa or Lba) at the other port << 50 m (for further study).		
NOTE 4: For ISDN transmission between Nat and Nbt at maximum length (insertion loss) according to TS 102 080 [1], 6.2.4.1, -4 dB degradation margin due to the parallel ADSL transmission.		

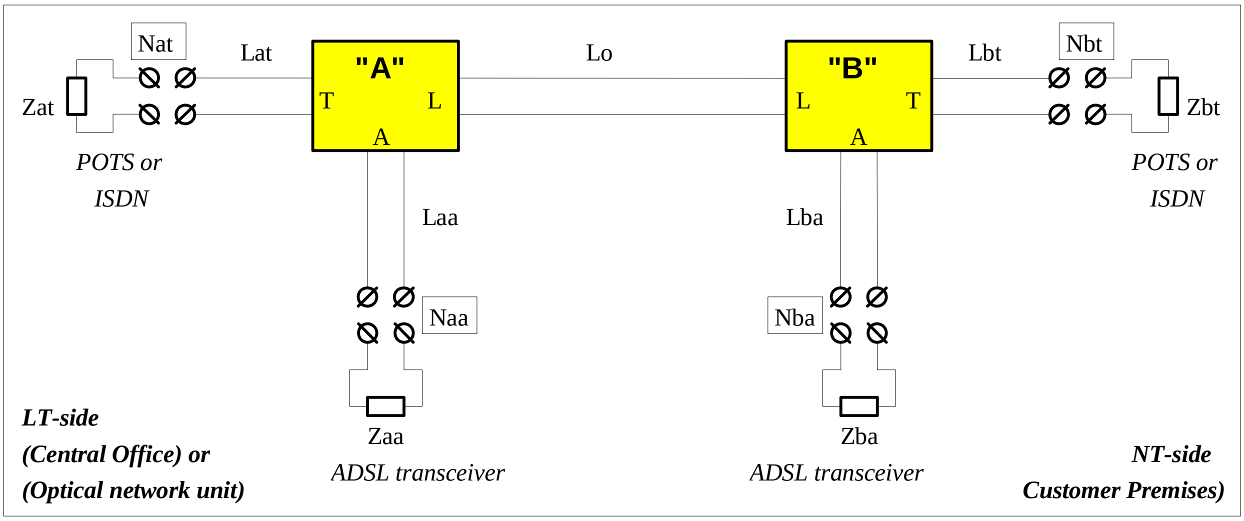


Figure 10: Functional diagram of the ADSL splitter configuration

Port "A" of the splitter-filter connects to the ADSL transceiver. Port "T" connects to the existing POTS or ISDN-BA equipment. Port "L" connects to the line.

The signal transfer between the different ports of the splitter can be understood as follows:

- The signal from port "T" to "L" passes through a low-pass filter, and so does the signal in the reverse direction.
- Exceptional isolation is required from port "A" to "T" to prevent undesirable interaction between ADSL and any existing narrowband services.
- The signal from port "A" to "L" sees a low order DC blocking high-pass filter, and so does the signal in the reverse direction. This simplified filter is applicable only for ADSL transceivers with sufficient high-pass filtering build-in.

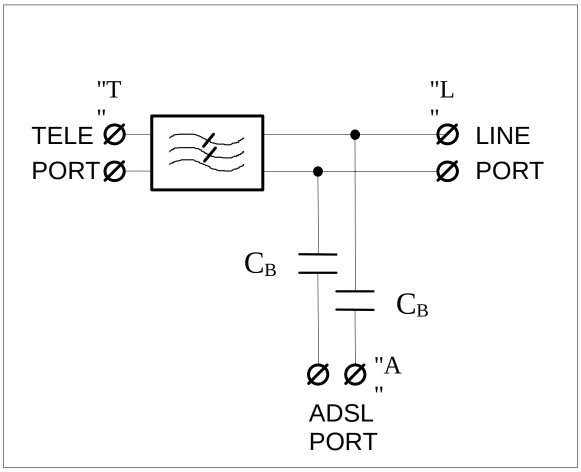


Figure 11: Structure of the ADSL splitter filter

6.2 Splitter requirements

6.2.1 DC requirements

When the splitter is to support ADSL over POTS the splitter shall meet the requirements specified in TR 101 728 [6], clause 5.1.

When the splitter is to support ADSL over ISDN, the DC requirements are as specified in TR 101 728 [6], clause 5.1, however the following modifications apply:

- DC loop current as specified in TS 102 080 [1].
- DC series resistance requirement is < 12,5 Ω for ADSL/ISDN splitter.

6.2.2 Terminating Impedances

When the splitter is to support ADSL over POTS, the terminating impedances specified in TR 101 728 [6], clause 5.2 are to be used.

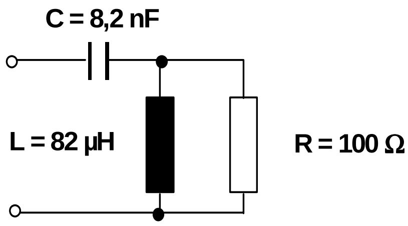
When the splitter is to support ADSL over ISDN, the terminating impedances given in clauses 6.2.2.1, 6.2.2.2 and 6.2.2.3 are to be used.

6.2.2.1 Z_{ADSL-I} for ADSL/ISDN splitter

In most of the tests with ISDN frequencies, the ADSL port is terminated with an impedance called Z_{ADSL-I}. Z_{ADSL-I} represents the input impedance of the ADSL transceiver (with the HPF), as seen from the splitter. This substitute circuit is a model which shall be applied to an ISDN-BA (2B1Q and 4B3T (see note)) splitter when verifying requirements of the low pass filter.

NOTE: The linecode MMS43 is referred to as 4B3T in the present document.

This impedance network is given in figure 12.



NOTE: Z_{ADSL-I} includes the blocking capacitors C_B.

Figure 12: Schematic diagram of the impedance Z_{ADSL-I}

The model in figure 12 is intended for splitter specification in the context of this clause. It is not a requirement on the input impedance of the ADSL transceiver.

6.2.2.2 Z_T and Z_L for ADSL/ISDN splitter

For requirements relating to ISDN band frequencies described in the present document, the terminating impedance Z_T is used to terminate the ISDN port, while Z_L is used to terminate the Line port. Z_T is defined as being equal to Z_L, and both shall follow the definitions of ETSI TS 102 080 [1], annex A for 2B1Q (135 Ω) and ETSI TS 102 080 [1], annex B for 4B3T (150 Ω) ISDN-BA.

6.2.2.3 C_B (blocking capacitor for ADSL/ISDN splitter)

A blocking capacitor of C_B = 27 nF, with C_B as defined by figure 11, shall be applied to ISDN-BA (2B1Q and 4B3T).

6.2.3 Low pass filter passband loss requirements

When the splitter is to support ADSL over POTS the low pass filter of the splitter shall meet the requirements specified in TR 101 728 [6], clause 5.6. In addition, impedance requirements at 25 Hz and 50 Hz, as specified in TR 101 728 [6], clause 5.4, are to be met.

When the splitter is to support ADSL over ISDN 2B1Q or ADSL over ISDN 4B3T, the low pass filter of the splitter shall meet the requirements specified in clause 6.2.3.1 of the present document, when measured for one splitter only.

6.2.3.1 Insertion loss for ADSL/ISDN splitter

For an ADSL/ISDN 2B1Q splitter, the low pass filter of the splitter shall meet the requirements stated in table 52, when measured for one splitter only.

Table 52: Insertion loss requirements for splitters used with 2B1Q ISDN

Frequency band	Insertion Loss	$Z_T = Z_L$
1 kHz to 40 kHz	< 0,8 dB	135 Ω
40 kHz to 80 kHz	< 2 dB	135 Ω

For an ADSL/ISDN 4B3T splitter, the low pass filter of the splitter shall meet the requirements stated in table 53, when measured for one splitter only.

Table 53: Insertion loss requirements for splitters used with 4B3T ISDN

Frequency band	Insertion Loss	$Z_T = Z_L$
1 kHz to 60 kHz	< 1,2 dB	150 Ω
60 kHz to 80 kHz	< 2 dB	150 Ω

6.2.4 Return Loss requirements

When the splitter is to support ADSL over POTS the low pass filter of the splitter shall meet the requirements specified in TR 101 728 [6], clause 5.6.

For an ADSL/ISDN 2B1Q splitter, the low pass filter of the splitter shall meet the requirements stated in table 54, when measured for one splitter only.

Table 54: Return loss requirements for splitters used with 2B1Q ISDN

Frequency band	Return Loss	$Z_T = Z_L$
1 kHz to 40 kHz	> 16 dB	135 Ω
40 kHz to 80 kHz	> 14 dB	135 Ω

For an ADSL/ISDN 4B3T splitter, the low pass filter of the splitter shall meet the requirements stated in table 55, when measured for one splitter only.

Table 55: Return loss requirements for splitters used with 2B1Q ISDN

Frequency band	Return Loss	$Z_T = Z_L$
1 kHz to 60 kHz	> 16 dB	150 Ω
60 kHz to 80 kHz	> 14 dB	150 Ω

6.2.5 Unbalance about earth

When the splitter is to support ADSL over POTS the low pass filter of the splitter shall meet the requirements specified in TR 101 728 [6], clause 5.7.

When the splitter is to support ADSL over ISDN 2B1Q or ADSL over ISDN 4B3T the low pass filter of the splitter shall meet the requirements specified in clause 6.2.5.1 of the present document.

6.2.5.1 Longitudinal Conversion Loss (LCL) for ADSL/ISDN splitter

The Longitudinal Conversion Loss (LCL) at the L,T and A ports, according to figure 11, when measured according to the definitions of ITU-T Recommendation G.117 [8], clause 4.1.3 shall be:

LCL > 40 dB for f = 300 Hz to 30 kHz

LCL > 50 dB for f = 30 kHz to 1 104 kHz

LCL > 30 dB for f = 1 104 Hz to 5 MHz

6.2.6 Isolation requirements (Insertion Loss in ADSL band)

When the splitter is to support ADSL over POTS the low pass filter of the splitter shall meet the requirements specified in TR 101 728 [6], clause 5.8.

When the splitter is to support ADSL over ISDN 2B1Q the low pass filter of the splitter shall meet the requirements specified in table 56, when measured for one splitter only.

Table 56: Isolation requirements for splitters used with 2B1Q ISDN

Frequency band	Minimum Isolation	$Z_T = Z_L$
150 kHz to 1 104 kHz	65 dB	135 Ω

When the splitter is to support ADSL over ISDN 4B3T the low pass filter of the splitter shall meet the requirements specified in table 57, when measured for one splitter only.

Table 57: Isolation requirements for splitters used with 2B1Q ISDN

Frequency band	Minimum Isolation	$Z_T = Z_L$
150 kHz to 1 104 kHz	65 dB	150 Ω

6.2.7 Noise

When the splitter is to support ADSL over POTS the low pass filter of the splitter shall meet the requirements specified in TR 101 728 [6], clause 5.9.

When the splitter is to support ADSL over ISDN 2B1Q or ADSL over ISDN 4B3T the requirements of the low pass filter of the splitter with regard to noise are for further study.

6.2.8 Distortion and intermodulation

When the splitter is to support ADSL over POTS the low pass filter of the splitter shall meet the requirements specified in TR 101 728 [6], clause 5.10.

When the splitter is to support ADSL over ISDN 2B1Q or ISDN 4B3T there is no intermodulation requirement, and the distortion requirement is to be included in the noise requirement of clause 6.2.7 of the present document.

6.2.9 Delay distortion

When the splitter is to support ADSL over POTS the low pass filter of the splitter shall meet the requirements specified in TR 101 728 [6], clause 5.11.

When the splitter is to support ADSL over ISDN 2B1Q or ADSL over ISDN 4B3T the signal delay distortion of the low pass filter of the splitter shall be < 20 µs up to 80 kHz. The signal delay distortion is defined as the absolute difference between the minimum signal delay (as measured at a discrete frequency in the 0 to 80 kHz range) and the maximum signal delay as measured at a discrete frequency over the same frequency range.

6.2.10 POTS related requirements

In the case of the ADSL/POTS splitter, certain requirements are necessary with regard to metering, common mode impulses and high level POTS signals. These are detailed in TR 101 728 [6], clauses 5.12, 5.13 and 5.14.

6.2.11 ADSL related requirements

6.2.11.1 ADSL insertion loss

When a splitter is to support ADSL over POTS the insertion loss between L port and A port shall be as specified in table 58. The insertion loss given in table 58 is to be met when the A port is terminated with Z_{ADSL} independent from the termination at the T port.

Table 58: Insertion loss between LINE and ADSL port for ADSL-over-POTS splitters

Frequency range	Insertion loss between L and A port
30 kHz to 50 kHz	< 3 dB
50 kHz to 1 104 kHz	< 1 dB
NOTE: The frequencies given above assume that only blocking capacitors are contained in the ADSL path of the POTS splitter. In some regions of Europe it is expected that the splitter device will contain additional components forming at least a part of the high-pass-filter. The frequencies for these kind of splitters are for further study.	

When a splitter is to support ADSL over ISDN 2B1Q or ADSL over ISDN 4B3T the insertion loss between L port and A port shall be as specified in table 59. The insertion loss given in table 59 is to be met when the ADSL port is terminated with Z_{ADSL-I} independent from the termination at the T (ISDN) port.

Table 59: Insertion loss between LINE and ADSL port for ADSL-over-ISDN splitters

Frequency range	Insertion loss between L and A port
120 kHz to 170 kHz	< 3 dB
170 kHz to 1 104 kHz	< 1 dB

Annex A (normative): Cable primary parameters for the test loop-set

This annex provides primary constants for the cable sections in the test loops. The primary parameters vary with the frequency. Their values are given in tables A.1 to A.5.

NOTE: These cable parameters have been reproduced in ITU-T Recommendation G.996.1 and are expected to be the same there.

Table A.1: R' L' C' values for 0,32 mm PE cable (ADSL.PE032)

Frequency (kHz)	R' (Ω/km)	L' (µH/km)	C' (nF/km)
0,00	409,000	607,639	40,00
2,50	409,009	607,639	40,00
10,00	409,140	607,639	40,00
20,00	409,557	607,639	40,00
30,00	410,251	607,639	40,00
40,00	411,216	607,639	40,00
50,00	412,447	607,639	40,00
100,00	422,302	607,631	40,00
150,00	437,337	607,570	40,00
200,00	456,086	607,327	40,00
250,00	477,229	606,639	40,00
300,00	499,757	605,074	40,00
350,00	522,967	602,046	40,00
400,00	546,395	596,934	40,00
450,00	569,748	589,337	40,00
500,00	592,843	579,376	40,00
550,00	615,576	567,822	40,00
600,00	637,885	555,867	40,00
650,00	659,743	544,657	40,00
700,00	681,138	534,942	40,00
750,00	702,072	526,991	40,00
800,00	722,556	520,732	40,00
850,00	742,601	515,919	40,00
900,00	762,224	512,264	40,00
950,00	781,442	509,503	40,00
1 000,00	800,272	507,415	40,00
1 050,00	818,731	505,831	40,00
1 100,00	836,837	504,623	40,00

Table A.2: R' L' C' values for 0,4 mm PE cable (ADSL.PE04)

Frequency (kHz)	R' (Ω/km)	L' (μH/km)	C' (nF/km)
0,00	280,000	587,132	50,00
2,50	280,007	587,075	50,00
10,00	280,110	586,738	50,00
20,00	280,440	586,099	50,00
30,00	280,988	585,322	50,00
40,00	281,748	584,443	50,00
50,00	282,718	583,483	50,00
100,00	290,433	577,878	50,00
150,00	302,070	571,525	50,00
200,00	316,393	564,889	50,00
250,00	332,348	558,233	50,00
300,00	349,167	551,714	50,00
350,00	366,345	545,431	50,00
400,00	383,562	539,437	50,00
450,00	400,626	533,759	50,00
500,00	417,427	528,409	50,00
550,00	433,904	523,385	50,00
600,00	450,027	518,677	50,00
650,00	465,785	514,272	50,00
700,00	481,180	510,153	50,00
750,00	496,218	506,304	50,00
800,00	510,912	502,707	50,00
850,00	525,274	499,343	50,00
900,00	539,320	496,197	50,00
950,00	553,064	493,252	50,00
1 000,00	566,521	490,494	50,00
1 050,00	579,705	487,908	50,00
1 100,00	592,628	485,481	50,00

Table A.3: R' L' C' values for 0,5 mm PE cable (ADSL.PE05)

Frequency (kHz)	R' (Ω/km)	L' (μH/km)	C' (nF/km)
0,00	179,000	673,574	50,00
2,50	179,015	673,466	50,00
10,00	179,244	672,923	50,00
20,00	179,970	671,980	50,00
30,00	181,161	670,896	50,00
40,00	182,790	669,716	50,00
50,00	184,822	668,468	50,00
100,00	199,608	661,677	50,00
150,00	218,721	654,622	50,00
200,00	239,132	647,735	50,00
250,00	259,461	641,208	50,00
300,00	279,173	635,119	50,00
350,00	298,103	629,489	50,00
400,00	316,230	624,309	50,00
450,00	333,591	619,557	50,00
500,00	350,243	615,202	50,00
550,00	366,246	611,211	50,00
600,00	381,657	607,552	50,00
650,00	396,528	604,192	50,00
700,00	410,907	601,104	50,00
750,00	424,835	598,261	50,00
800,00	438,348	595,639	50,00
850,00	451,480	593,217	50,00
900,00	464,258	590,975	50,00
950,00	476,710	588,896	50,00
1 000,00	488,857	586,966	50,00
1 050,00	500,720	585,169	50,00

Table A.4: R' L' C' values for 0,63 mm PE cable (ADSL.PE063)

Frequency (kHz)	R' (Ω/km)	L' (µH/km)	C' (nF/km)
0,00	113,000	699,258	45,00
2,50	113,028	697,943	45,00
10,00	113,442	693,361	45,00
20,00	114,737	687,008	45,00
30,00	116,803	680,714	45,00
40,00	119,523	674,593	45,00
50,00	122,768	668,690	45,00
100,00	143,115	642,718	45,00
150,00	164,938	622,050	45,00
200,00	185,689	605,496	45,00
250,00	204,996	592,048	45,00
300,00	222,961	580,960	45,00
350,00	239,764	571,691	45,00
400,00	255,575	563,845	45,00
450,00	270,533	557,129	45,00
500,00	284,753	551,323	45,00
550,00	298,330	546,260	45,00
600,00	311,339	541,809	45,00
650,00	323,844	537,868	45,00
700,00	335,897	534,358	45,00
750,00	347,542	531,212	45,00
800,00	358,819	528,378	45,00
850,00	369,758	525,813	45,00
900,00	380,388	523,480	45,00
950,00	390,734	521,352	45,00
1 000,00	400,816	519,402	45,00
1 050,00	410,654	517,609	45,00
1 100,00	420,264	515,956	45,00

Table A.5: R' L' C' values for 0,9 mm PE cable (ADSL.PE09)

Frequency (kHz)	R' (Ω/km)	L' (μH/km)	C' (nF/km)
0,00	55,000	750,796	40,00
2,50	55,088	745,504	40,00
10,00	56,361	731,961	40,00
20,00	59,941	716,775	40,00
30,00	64,777	703,875	40,00
40,00	70,127	692,707	40,00
50,00	75,586	682,914	40,00
100,00	100,769	647,496	40,00
150,00	121,866	625,140	40,00
200,00	140,075	609,652	40,00
250,00	156,273	598,256	40,00
300,00	170,987	589,504	40,00
350,00	184,556	582,563	40,00
400,00	197,208	576,919	40,00
450,00	209,104	572,237	40,00
500,00	220,365	568,287	40,00
550,00	231,081	564,910	40,00
600,00	241,326	561,988	40,00
650,00	251,155	559,435	40,00
700,00	260,615	557,183	40,00
750,00	269,745	555,183	40,00
800,00	278,577	553,394	40,00
850,00	287,138	551,784	40,00
900,00	295,452	550,327	40,00
950,00	303,538	549,002	40,00
1 000,00	311,416	547,793	40,00
1 050,00	319,099	546,683	40,00
1 100,00	326,602	545,663	40,00

Annex B (normative): Definition of splitter parameters

B.1 Introduction

This annex gives the definitions of parameters which are specified in clause 6.2.

B.2 Insertion loss or isolation definition

The splitter filter shall be near transparent from port "T" to "L" (and reverse) within the relevant frequency band. This means that the injected voltage U_T observed at port "T" is close to the transferred voltage U_L observed at port "L". In this example, where signals are injected in port "T", these impedances are:

- a range of line impedances Z_L around a nominal value Z_{L0}, that are terminating port "L";
- a range of ADSL impedances Z_X, around a nominal value Z_{X0}, that are terminating port "X".

Similar properties apply for signals injected in port "X" or port "L".

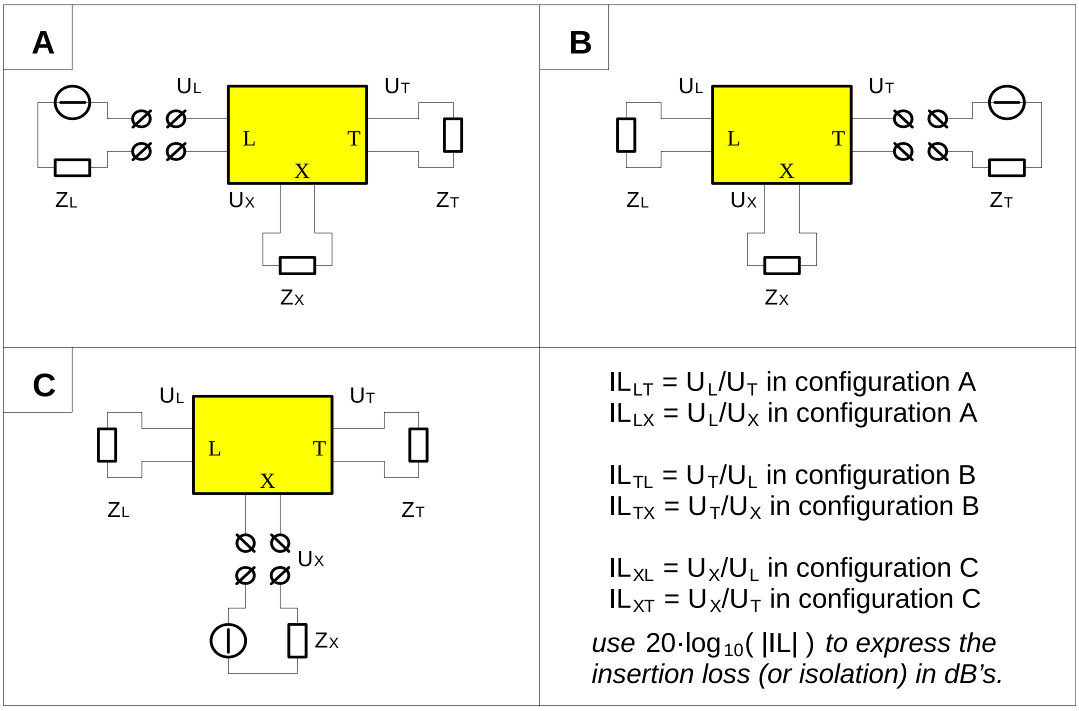


Figure B.1: Configuration that defines the insertion loss of a single splitter filter

B.3 Return loss definition

The splitter filter shall be near transparent from port "T" to "L" (and reverse) within the relevant frequency band. This means that the impedance Z_{TT} observed at port "T" equals the line impedance Z_L connected to port "L". In this example, where signals are injected in port "T", these impedances are:

- a range of line impedances Z_L around a nominal value Z_{L0}, that are terminating port "L";
- a range of ADSL impedances Z_X, around a nominal value Z_{X0}, that are terminating port "X".

Similar properties apply for signals injected in port "X" or port "L".

The requirements can be defined in terms of an impedance ratio (in this example Z_{TT}/Z_L) or in terms of a return loss (in this example $(Z_{LL} + Z_T)/(Z_{LL}-Z_T)$). These two quantities are interrelated. In this requirement, the return loss definitions are dedicated to the basic design goal of "near transparency".

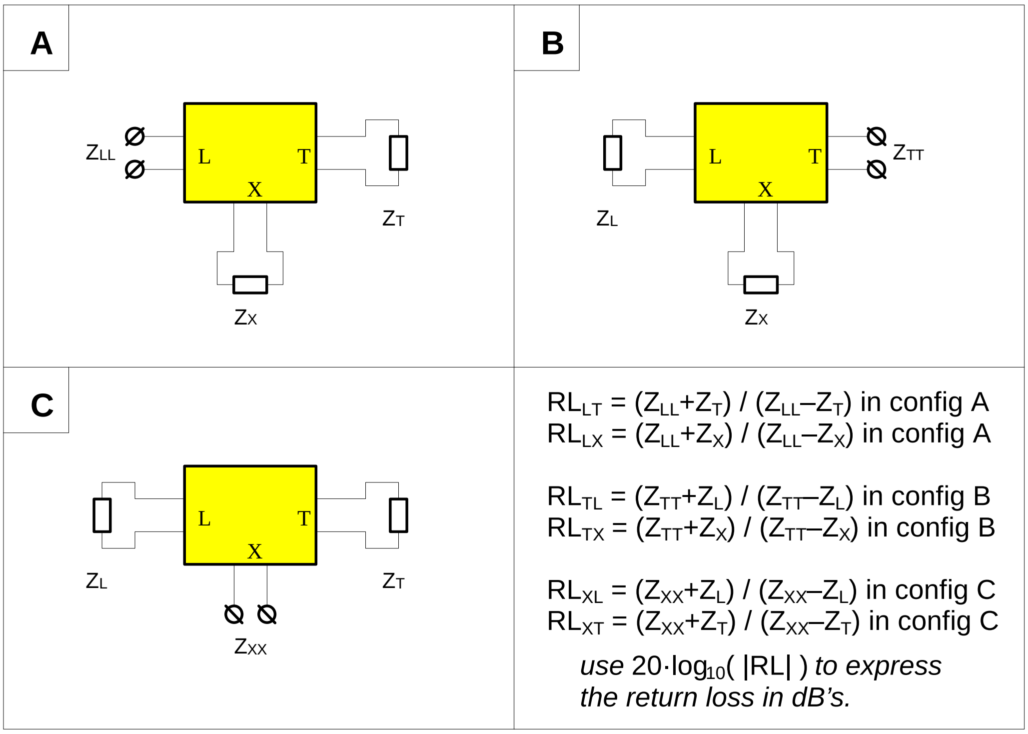


Figure B.2: Configuration that defines the return loss of a single splitter filter

B.4 Longitudinal Conversion Loss definition (LCL)

As described in ITU-T Recommendation G.117 [8], clause 4.1.3.

Annex C (normative): ADSL over ISDN configuration of T1.413 based modems

This annex describes the ADSL over ISDN configuration of modems based on ANSI T1.413 [9]. The annex is provided for information to enhance backward compatibility with legacy modems.

C.1 Introduction

The ADSL signals described in this clause shall be allocated above the operating band of ISDN-BA signals based on 2B1Q/4B3T line signals as those defined in TS 102 080 [1]. In order to allow sufficient upstream bandwidth capacity the ATU-R shall have a transmission bandwidth making use of tones 33 to 63. The use of an extended range making use of tones between 1 and 63 is optional.

The IDFT implementation at the ATU-R side shall be implemented as follows. Tones 33 to 63 will contain complex values generated by the encoder and scaler.

The values in tones 1 to 31 shall be:

a) mirrored complex-conjugate of tones 33 to 63 if the transmitter uses only 32 tones (tone #32 = 0);

b) zero if the transmitter uses 64 tones and the receiver uses 32 tones (tone #32 = 0);

c) complex data generated by the encoder and scaler if both the transmitter and receiver use 64 tones (tone 32 also equals value generated by encoder and scaler).

The information whether the upstream transmitter and/or receiver uses 32 or 64 tones is communicated via activation and acknowledgement tones constituting a handshake procedure.

C.2 ATU-C

C.2.1 Used frequency band

The ATU-C shall use tones between #33 (f = 142,3125 kHz) and #255 (f = 1 099,6875 kHz). The use of tones below #33 is optional.

C.2.2 Nominal aggregate power level

The nominal aggregate power level shall be 19,83 dBm.

C.2.3 Pilot frequency

Tone #96 (f = 414 kHz) shall be reserved for a pilot (see ITU-T Recommendation G.992.1 [2], clause 6.11.1.2); that is $b_{96} = 0$ and $g_{96} = 1$.

C.2.4 Transmit spectral mask

The ATU-C transmitter spectral response shall be as defined in clause 4.2.1.1.

C.3 ATU-R

C.3.1 ATU-R transmitter reference models

The ATU-R reference model for STM transport is given in figure C.1.

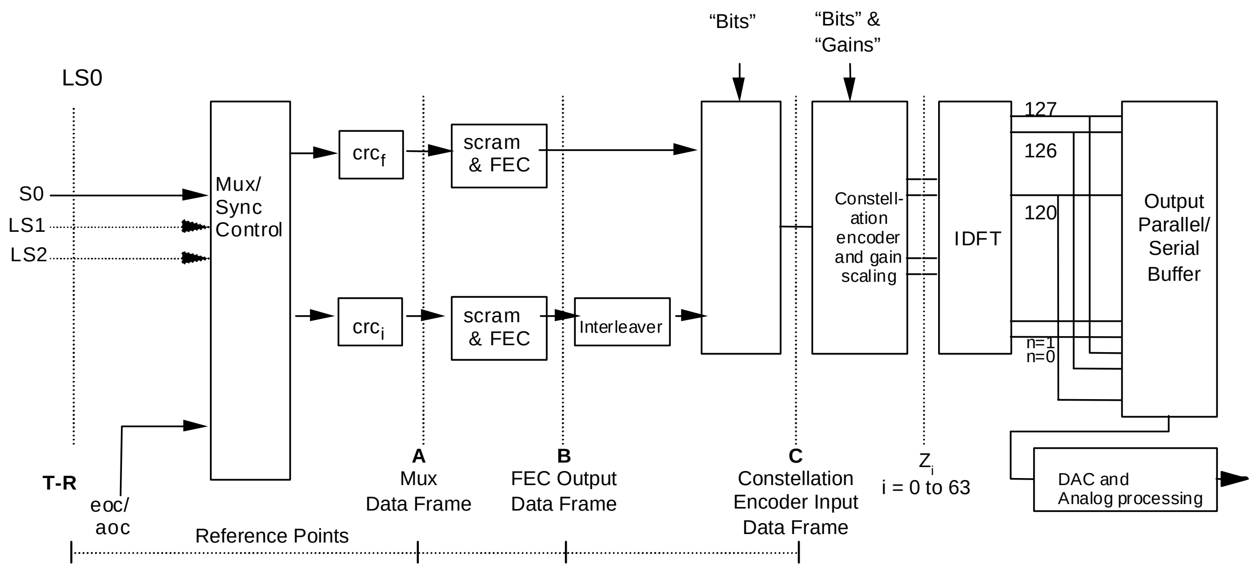


Figure C.1: ATU-R transmitter reference model for STM transport

The ATU-R reference model for ATM transport is given in figure C.2.

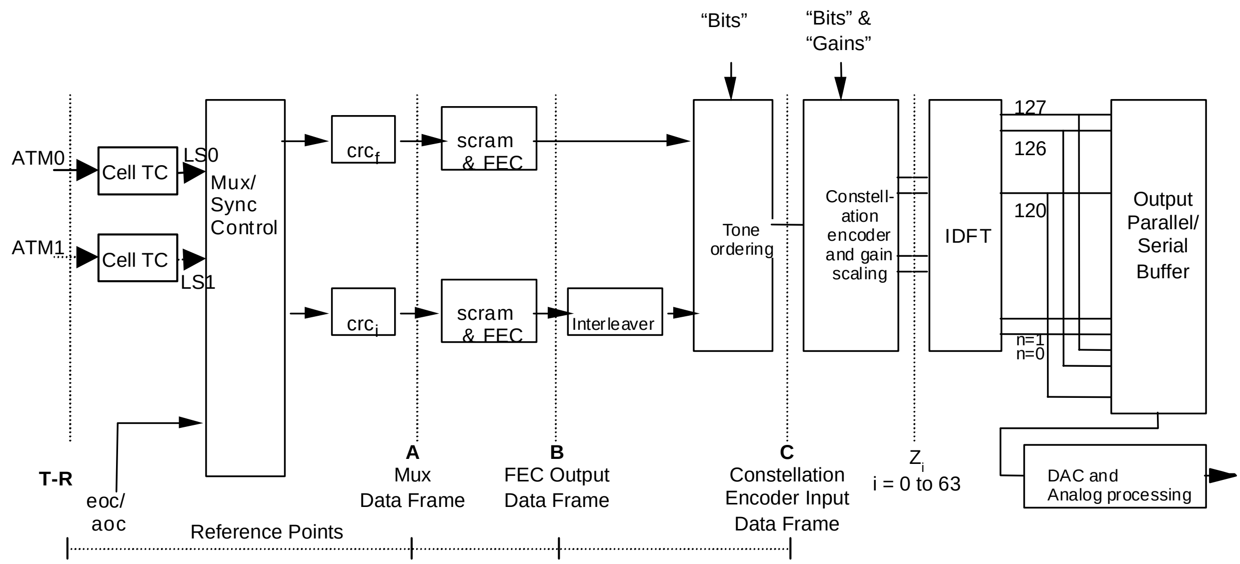


Figure C.2: ATU-R transmitter reference model for ATM transport

C.3.2 Used frequency band

The ATU-R shall use tones between #33 and #63. The use of tones below #33 is optional.

C.3.3 Nominal aggregate power level

The nominal aggregate power level shall be 13,26 dBm.

C.3.4 Maximum number of data sub-carriers

The maximum number of data sub-carriers shall be 63, however the use of carriers between #1 and #32 is optional. The lower frequency limit of the used sub-carriers is partly determined by the ISDN splitting filters. If FDM is used to separate the upstream and downstream ADSL signals, the upper limit is set by down-up splitting filters. The cut-off frequencies of these filters are completely at the discretion of the manufacturer. The range of usable bandwidth is determined during the channel estimation.

C.3.5 Pilot frequency

There is no upstream pilot, the ATU-R shall perform slave loop timing based on the downstream pilot.

C.3.6 Nyquist frequency

The upstream Nyquist frequency shall be at sub-carrier #64 (f = 276 kHz).

C.3.7 Modulation by the Inverse Discrete Fourier Transform

The modulating transform defines the relationship between the 128 real values x_k and the $Z_i^{'}$:

$$x_k = \sum_{i=0}^{127} \exp\left(\frac{j\pi ki}{64}\right) Z_i^{'} \qquad \text{for } k = 0 \text{ to } 127$$

The encoder and scaler generate complex values of Zi corresponding to tones 1 to 63 (plus zero at dc and one real value if the Nyquist frequency is used). In order to generate real values of x_k these values shall be augmented so that the vector $Z_i^{'}$ has Hermitian symmetry. That is,

$$Z_i^{'} = \text{conj}[Z_{128-i}^{'}] \qquad \text{for } i = 65 \text{ to } 128$$

If the transceiver receives C-ACT1 during transceiver training then,

$$Z_i^{'} = 0 \qquad \text{for } i = 1 \text{ to } 32$$

NOTE: For the mirrored complex conjugate transmitter,

$$Z_i^{'} = \text{conj}[Z_{64-i}^{'}] \qquad \text{for } i = 1 \text{ to } 31$$

$$Z_{32}^{'} = 0$$

C.3.8 Synchronization symbol

The data pattern used in the synchronization symbol shall be the pseudo-random sequence PRU (d_n , for n = 1 to 128), defined by:

$$d_n = 1 \qquad \text{for } n = 1 \text{ to } 6$$

$$d_n = d_{n-5} \oplus d_{n-6} \qquad \text{for } n = 7 \text{ to } 128$$

The bits are used as follows: the first pair of bits (d_1 and d_2) is used for the dc and Nyquist sub-carriers (the power assigned to them is, of course, zero, so the bits are effectively ignored); then the first and second bits of subsequent pairs shall be used to define the X_i and Y_i for i = 1 to 63 in accordance to table 16 of ITU-T Recommendation G.992.1 [2].

C.3.9 Cyclic prefix

The last 8 samples of the output of the IDFT (x_k for k = 120 to 127) shall be prepended to the block of 64 samples and read out to the DAC in sequence. That is, the subscript, k, of the DAC samples in sequence are 120 to 127, 0 to 127.

C.3.10 Transmit spectral mask

The ATU-R transmitter spectral response shall be as defined in clause 4.2.1.2.

C.4 Initialization

C.4.1 C-Activate

C-ACT2m or C-ACT2e shall be sent to initiate a communication link to the ATU-R.

As shown in table C.1, the ATU-C shall transmit C-ACT2m or C-ACT2e to indicate its ability to receive 32 or 64 upstream tones.

Table C.1

	ATU-C Receiver
C-ACT2m	Tones above 32 only
C-ACT2e	Tones below 33 allowed

C.4.2 C-ACT2m

ATU-C shall transmit C-ACT2m to indicate that it is able to receive tones above 32 only.

C-ACT2m is a single frequency sinusoid at $f_{C\text{-}ACT2m}$ = 319,125 kHz defined as in ITU-T Recommendation G.992.1 [2], clause 9.2.1.3, but with k = 74.

The level and duration of C-ACT2m shall be the same as those of C-ACT1 (see ITU-T Recommendation G.992.1 [2], clause 9.2.2.1).

C-QUIET2 immediately follows C-ACT2m.

C.4.3 C-ACT2e

ATU-C shall transmit C-ACT2e to indicate that it is able to receive tones below 33.

C-ACT2e is a single frequency sinusoid at $f_{C\text{-}ACT2e}$ = 327,75 kHz defined as in ITU-T Recommendation G.992.1 [2], clause 9.2.1.3, but with k = 76.

The level and duration of C-ACT2e shall be the same as those of C-ACT1 (see ITU-T Recommendation G.992.1 [2], clause 9.2.2.1).

C-QUIET2 immediately follows C-ACT2e.

NOTE: The sets of downstream tones defined in the present document do not include the C-TONE (defined in ITU-T Recommendation G.992.1 [2]). In the future C-TONE might disappear completely. However, for a purely tone based activation of ADSL over ISDN the ETSI TM6 decided that it must be defined. The use of tone 82 is under study in SP11 of the living list of work item RTS/TM-06006.

C.4.4 R-Acknowledgment

As shown in table C.2, the ATU-R shall transmit R-ACK1m/e or R-ACK2m/e as acknowledgment to C-ACT2e/m to indicate whether it use 32 or 64 tones for upstream transmission.

Table C.2

	R-ACK1m	**R-ACK1e**	**R-ACK2m**	**R-ACK2e**
C-QUIET3	PILOT QUIET		PILOT	
C-QUIET4	PILOT		PILOT	
C-QUIET5	QUIET		PILOT	
ATU-R Tx Carriers	33 to 63 only	33 to 63 mandatory 1 to 32 optional	33 to 63 only	33 to 63 mandatory 1 to 32 optional

C.4.5 R-ACT-REQ

R-ACT-REQ is a single frequency sinusoid at $f_{R\text{-}ACT\text{-}REQ}$ = 181,125 kHz defined as in ITU-T Recommendation G.992.1 [2], clause 9.2.1.3, but with k = 42.

C.4.6 R-ACK1m

R-ACK1m is a single frequency sinusoid at $f_{R\text{-}ACK1m}$ = 189,75 kHz defined as in ITU-T Recommendation G.992.1 [2], clause 9.2.1.3, but with k = 44.

C.4.7 R-ACK1e

R-ACK1e is a single frequency sinusoid at $f_{R\text{-}ACK1e}$ = 198,375 kHz defined as in ITU-T Recommendation G.992.1 [2], clause 9.2.1.3, but with k = 46.

C.4.8 R-ACK2m

R-ACK2m is a single frequency sinusoid at $f_{R\text{-}ACK2m}$ = 207 kHz defined as in ITU-T Recommendation G.992.1 [2], clause 9.2.1.3, but with k = 48.

C.4.9 R-ACK2e

R-ACK2e is a single frequency sinusoid at $f_{R\text{-}ACK2e}$ = 215,625 kHz defined as in ITU-T Recommendation G.992.1 [2], clause 9.2.1.3, but with k = 50.

C.4.10 C-REVEILLE

C-REVEILLE is a single frequency sinusoid at $f_{C\text{-}REVEILLE}$ = 336,375 kHz defined as in ITU-T Recommendation G.992.1 [2], clause 9.2.1.3, but with k = 78.

C.4.11 C-PILOT1

C-PILOT1 is a single frequency sinusoid at $f_{C\text{-}PILOT1}$ = 414 kHz defined as in ITU-T Recommendation G.992.1 [2], clause 9.2.1.3, but with k = 96.

C.4.12 R-REVERB1

The data pattern used in R-REVERB1 shall be the pseudo-random sequence PRU (d_n , for n = 1 to 128), defined by:

$$d_n = 1 \qquad \text{for } n = 1 \text{ to } 6$$

$$d_n = d_{n-5} \oplus d_{n-6} \qquad \text{for } n = 7 \text{ to } 128$$

The bits are used as follows: the first pair of bits (d_1 and d_2) is used for the dc and Nyquist sub-carriers (the power assigned to them is, of course, zero, so the bits are effectively ignored); then the first and second bits of subsequent pairs shall be used to define the X_i and Y_i for i = 1 to 63 as defined for C-REVERB1in table 16 of ITU-T Recommendation G.992.1 [2].

NOTE: The d_1 to d_6 are re-initialized for each symbol , so each symbol of R-REVERB1 uses the same data.

C.4.13 R-MEDLEY

R-MEDLEY is a wide band pseudo-random signal used for estimation of the upstream SNR at the ATU-C. The data to be transmitted are derived from the pseudo-random sequence PRU defined in R-REVERB1 clause. In contrast to R-REVERB1, however, the cyclic prefix is used and the data sequence continue from one symbol to the next. Because the sequence is of length 63, and 128 bits are used for each symbol, the sub-carrier vector for R-MEDLEY changes from one symbol to the next. R-MEDLEY is transmitted for 16 384 symbol periods. Following R-MEDLEY the ATU-R enters signalling state R-REVERB4.

C.4.14 C-MSGS2

Two bits are encoded onto each of the sub-carriers numbered 75 through 78 using 4QAM constellation labelling given in clause 6.11.3 and table 16 of ITU-T Recommendation G.992.1 [2]. The same bits are also encoded in the same way onto a set of backup carriers, namely, sub-carriers 91 through 94. The least significant byte of the message is transmitted in the first symbol of C-MSGS2, with the two least significant bits of each byte encoded onto carriers 75 and 91. In addition, the pilot subcarrier 96 shall be modulated with the (+, +) constellation point.

C.4.15 R-MSGS2

Two bits are encoded onto each of the sub-carriers numbered 44 through 47 using 4QAM constellation labelling given in clause 6.11.3 and table 16 of ITU-T Recommendation G.992.1 [2]. The same bits are also encoded in the same way onto a set of backup carriers, namely, sub-carriers 49 through 52. The least significant byte of the message is transmitted in the first symbol of C-MSGS2, with the two least significant bits of each byte encoded onto carriers 44 and 49.

C.4.16 C-ECT and R-ECT

Because C-ECT and R-ECT are vendor defined signals (see ITU-T Recommendation G.992.1 [2], clauses 9.4.9 and 9.5.5) the PSD specification shall be interpreted only as a maximum. This maximum level is -39 -2n dBm/Hz (for C-ECT) and -37 dBm/Hz (for R-ECT) (with n indicating the power cut back, n = 0 to 6) for the band from 138 kHz to 1 104 kHz (for C-ECT) and to 276 (for R-ECT). Subcarriers 1 to 31 may be used, but the power in the ISDN band shall conform to the specification given in clauses C.2.4 and C.3.10 of the present document.

C.4.17 Power Cut-back

If the total upstream power measured on sub-carriers 40 to 51 during R_REVERB1 is greater than 0 dBm, then the PSD for C-REVERB1 and all subsequent downstream signals shall be as shown in table C.3.

Table C.3: Power cut-back: downstream PSD as a function of upstream received power

Upstream received power (dBm) <	0	1,5	3	4,5	6	7,5	9
Max downstream PSD (dBm/Hz)	-40	-42	-44	-46	-48	-50	-52

This chosen level shall become the reference level for all subsequent gain calculations.

C.4.18 C-B&G

C-B&G shall be used to transmit to the ATU-R the bits and gains information, {i.e. $b_1, g_1, b_2, g_2, \ldots b_{63}, g_{63},$}, that are to be used on the upstream carrierS. b_i indicates the number of bits to be coded by the ATU-R transmitter onto the i^{th} upstream carrier; g_i indicates the scale factor, relative to the gain that was used for that carrier during the transmission of R-MEDLEY, that shall be applied to the i^{th} upstream carrier. Because no bits or energy shall be transmitted at dc or one-half the sampling rate, b_0, g_0, b_{64}, and g_{64} shall all be presumed to be zero and shall not be transmitted.

Each b_i shall be represented as an unsigned 4-bit integer, with valid b_is lying in the range of zero to N_{upmax}, the maximum number of bits that the ATU-R is prepared to modulate onto any sub-carrier, which is communicated in R-MSGS1.

Each g_i shall be represented as an unsigned 12-bit fixed-point quantity, with the binary point assumed just to the right of the third most significant bit. For example, a g_i with binary representation (most significant bit listed first) 001.010000000 would instruct the ATU-R to scale the constellation for carrier *i*, by a gain factor of 1,25, so that the power in that carrier shall be 1,94 dB higher than it was during R-MEDLEY.

For sub-carriers on which no data are to be transmitted, and the receiver will never allocate bits (e.g., out-of-band sub-carriers) both b_i and g_i shall be set to zero (0000 and 00000000 0000, respectively). For sub-carriers on which no data are to be currently transmitted, but the receiver may allocate bits later (e.g. as a result of an SNR improvement), the b_i shall be set to zero and the g_i to 1 a value in the 0,75 to 1,33 range (000.1100000 00 to 001.010101011).

A total of 126 bits and gains information is to be transmitted during C B&G, and a total of 126 symbol period is required, using the method described in ITU-T Recommendation G.992.1 [2], clause 9.8.9. Following C-B&G the ATU-C shall enter state C-CRC5.

The C-B&G information shall be mapped in a 1 008-bit message *m* defined by:

$$m = \{m_{1\,007}, m_{1\,006}, \ldots, m_1, m_0\} = \{g_{63}, b_{63}, \ldots g_1, b_1\},$$

with the msb of b_i and g_i in the higher *m* index and m_0 being transmitted first. The message *m* shall be transmitted in 126 symbols, using the transmission method as described in ITU-T Recommendation G.992.1 [2], clause 9.8.9.

Following C-B&G, the ATU-C shall enter the state C-CRC5. The modified timing diagram of the initialization sequence (part 2) is shown in figure C.3.

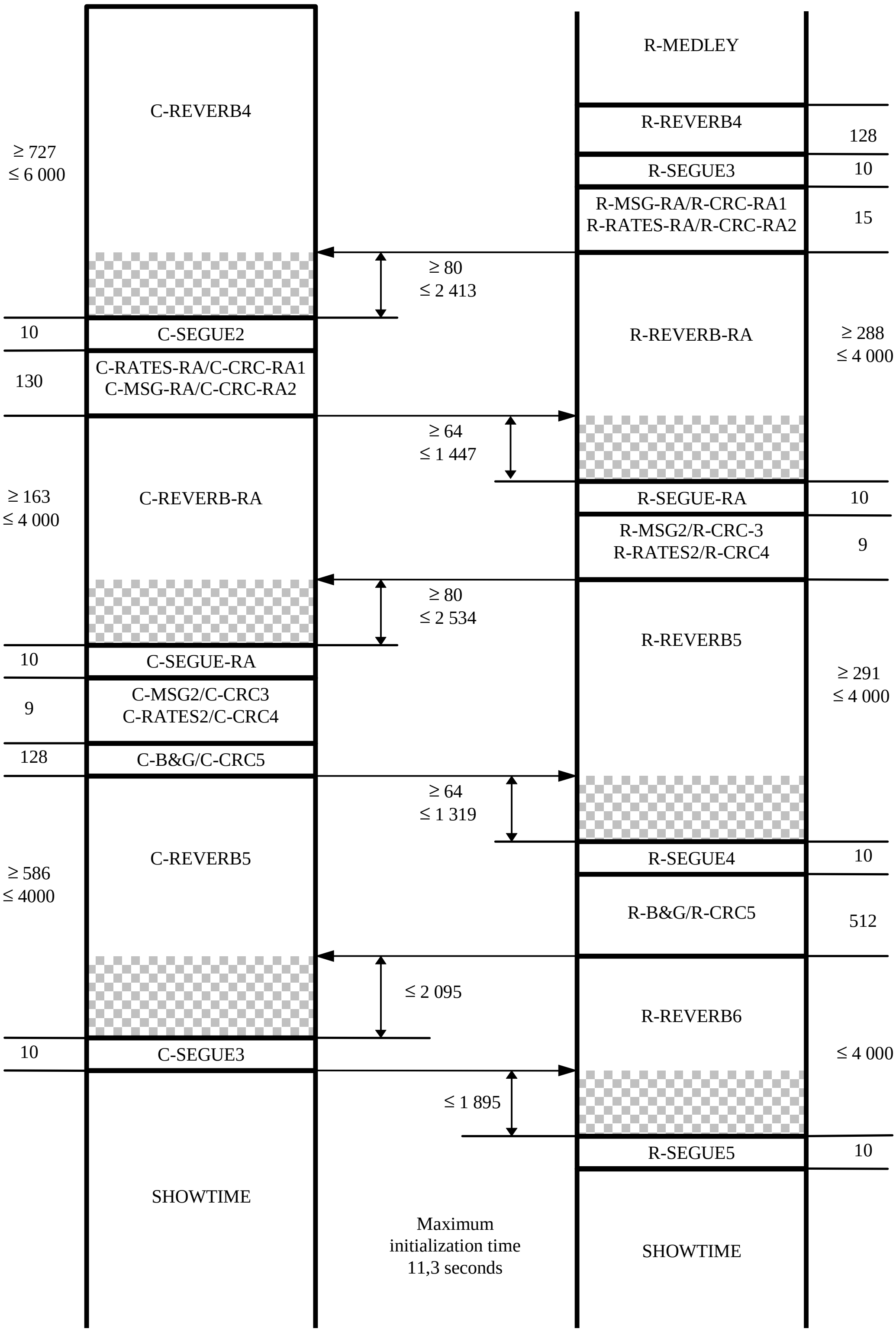


Figure C.3: Timing diagram of the initialization sequence

Annex D (informative): PSD masks for ADSL over POTS as specified in G.992.1

In this annex, the PSD masks for ADSL over POTS are reproduced. The PSD masks are copied from annex A of ITU-T Recommendation G.992.1 [2].

D.1 ATU-C downstream transmit spectral mask

The band from 25 kHz to 1 104 kHz that is referred to is the widest possible band (used for ADSL over POTS implemented with overlapped spectrum). Limits defined within this band apply also to any narrower bands used.

Figure D.1 shows a representative spectral mask for the transmit signal. The low-frequency stop-band is defined as the POTS band, the high-frequency stop-band is defined as frequencies greater than 1 104 kHz.

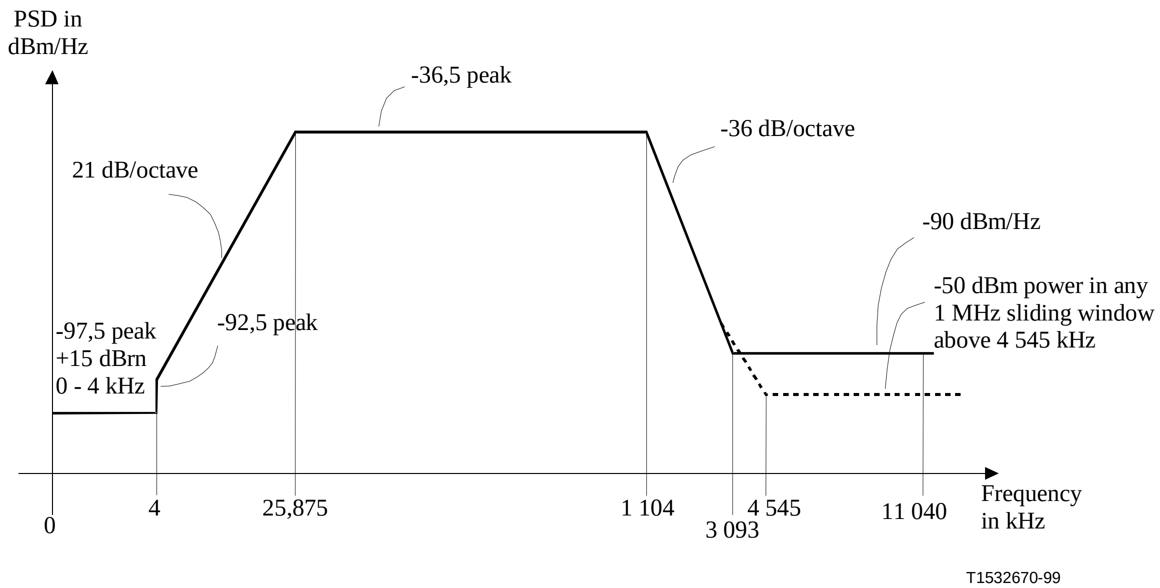


Figure D.1: ATU-C transmitted PSD mask

Table D.1: Line equations for ATU-C transmitted PSD mask

Frequency band *f* (kHz)	Equation for line (dBm/Hz)
0 < *f* < 4	-97,5, with max power in the in 0 - 4 kHz band of +15 dBrn
4 < *f* < 25,875	$-92,5 + 21 \times \log_2 (f/4)$
25,875 < *f* < 1 104	-36,5
1 104 < *f* < 3 093	$-36,5 - 36 \times \log_2 (f/1\,104)$
3 093 < *f* < 4 545	-90 peak, with max power in the [*f*, *f* + 1 MHz] window of $(-36,5 - 36 \times \log_2 (f/1\,104) + 60)$ dBm
4 545 < *f* < 11 040	-90 peak, with max power in the [*f*, *f* + 1 MHz] window of -50 dBm

NOTE 1: All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.
NOTE 2: The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate.
NOTE 3: Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.
NOTE 4: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.
NOTE 5: The step in the PSD mask at 4 kHz is to protect V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of -97,5 dBm/Hz at 3 400 Hz. It was recognized that this might impact V.90 performance, and so the floor was extended to 4 kHz.
NOTE 6: All PSD and power measurements shall be made at the U-C interface (see figure 1.1); the signals delivered to the PSTN are specified in annex E.

D.2 ATU-C Transmitter PSD Mask for Reduced NEXT

Figure D.2 defines a spectral mask for the ATU-C transmitted signal, which results in reduced NEXT into the ADSL upstream band, relative to the mask in clause D.1. Adherence to this mask will in many cases result in improved upstream performance of the other ADSL systems in the same or adjacent binder group, with the improvement dependent upon the other interferers. This mask differs from the mask in clause D.1 only in the band from 4 kHz to 138 kHz.

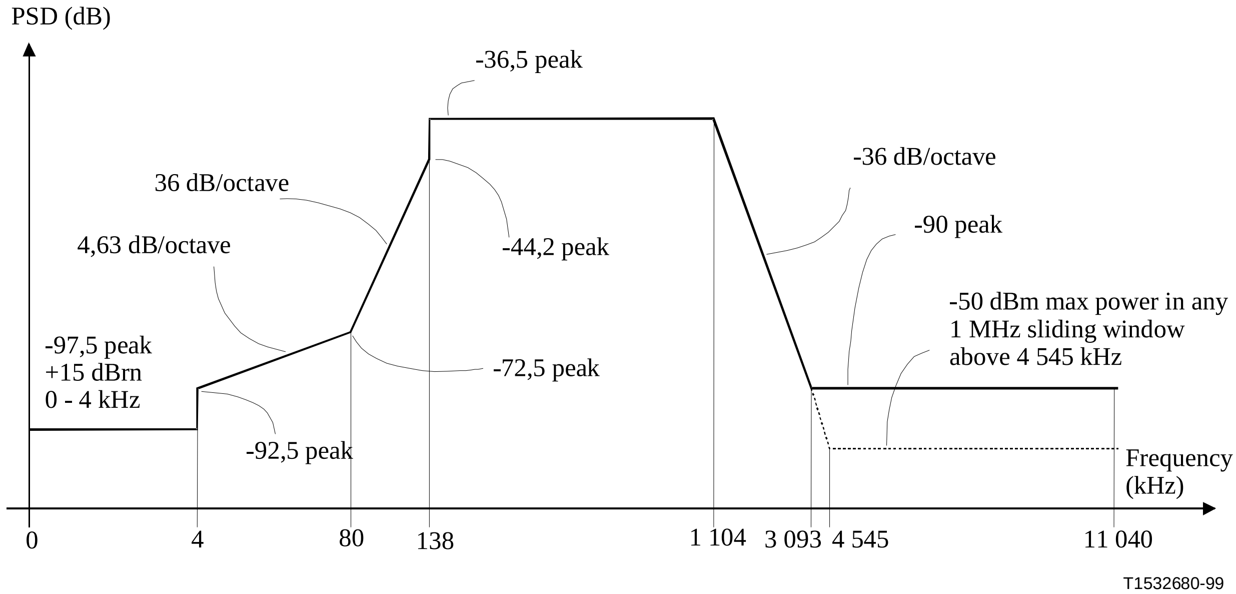


Figure D.2: ATU-C transmitter PSD mask for reduced NEXT

Table D.2: Line equations for ATU-C transmitted PSD mask for reduced NEXT

Frequency band *f* (kHz)	Equation for line (dBm/Hz)
0 < f < 4	-97,5, with max power in the in 0 - 4 kHz band of +15 dBrn
4 < f < 80	$-92,5 + 4,63 \times \log_2 (f/4)$
80 < f < 138	$-72,5 + 36 \times \log_2 (f/80)$
138 < f < 1 104	-36,5
1 104 < f < 3 093	$-36,5 - 36 \times \log_2(f/1\,104)$
3 093 < f < 4 545	-90 peak, with max power in the [f, f + 1 MHz] window of $(-36,5 - 36 \times \log_2(f/1\,104) + 60)$ dBm
4 545 < f < 11 040	-90 peak, with max power in the [f, f + 1 MHz] window of -50 dBm

NOTE 1: All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.
NOTE 2: The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate.
NOTE 3: Above 25,875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.
NOTE 4: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.
NOTE 5: The step in the PSD mask at 4 kHz is to protect V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of -97,5 dBm/Hz at 3 400 Hz. It was recognized that this might impact V.90 performance, and so the floor was extended to 4 kHz.
NOTE 6: All PSD and power measurements shall be made at the U-C interface (see figure 1.1); the signals delivered to the PSTN are specified in annex E.

D.3 ATU-R Transmitter spectral mask

Figure D.3 shows a PSD mask for the transmitted signal. The passband is defined as frequency range over which the modem transmits, which may be narrower than the 25,875 to 138 kHz shown. The low-frequency stop-band is defined as the voiceband.

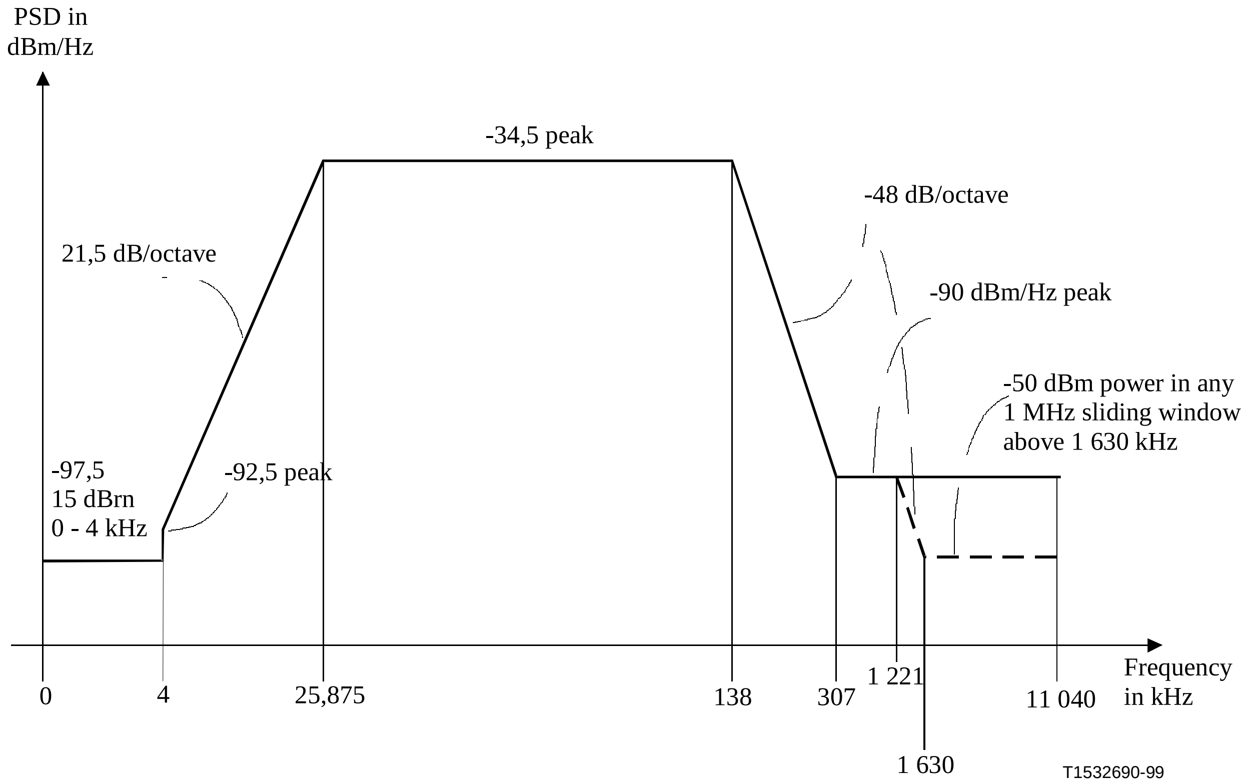


Figure D.3: ATU-R transmitter PSD mask

Table D.3: Line equations for ATU-R transmitted PSD mask

Frequency band *f* (kHz)	**Equation for line (dBm/Hertz)**
0 < *f* < 4	-97,5, with max power in the in 0 - 4 kHz band of +15 dBrn
4 < *f* < 25,875	$-92{,}5 + 21{,}5 \times \log_2(f/4)$
25,875 < *f* < 138	-34,5
138 < *f* < 307	$-34{,}5 - 48 \times \log_2(f/138)$
307 < *f* < 1 221	-90
1 221 < *f* < 1 630	-90 peak, with max power in the [*f*, *f* + 1 MHz] window of $(-90 - 48 \times \log_2(f/1\,221) + 60)$ dBm
1 630 < *f* < 11 040	-90 peak, with max power in the [*f*, *f* + 1 MHz] window of -50 dBm

NOTE 1: All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.
NOTE 2: The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate.
NOTE 3: Above 25,875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.
NOTE 4: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.
NOTE 5: The step in the PSD mask at 4 kHz is to protect V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of -97,5 dBm/Hz at 3 400 Hz. It was recognized that this might impact V.90 performance, and so the floor was extended to 4 kHz.
NOTE 6: All PSD and power measurements shall be made at the U-C interface (see figure 1.1); the signals delivered to the PSTN are specified in annex E.

Annex E (Informative): Transmission and reflection of cable sections

E.1 Definition of transmission function and insertion loss

Transmission function and insertion loss are quantities that are related to the values of the (complex) source and load impedance. Within the context of the present document, a simplified definition is used in which source and load are the same and equal to a real value R_N. The transmission function and insertion loss associated with a two-port network, normalized to a chosen reference resistance R_N, are defined as the following voltage ratios (see figures E.1 and E.2):

$$\text{Transmission Function} = \frac{U_2}{U_1} \quad (1)$$

$$\text{Insertion Loss} = \frac{U_1}{U_2} \quad (2)$$

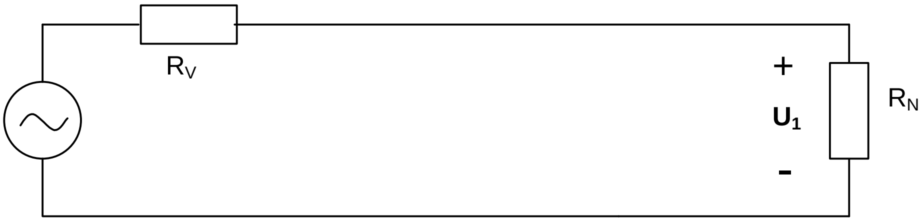


Figure E.1: Voltage across the load

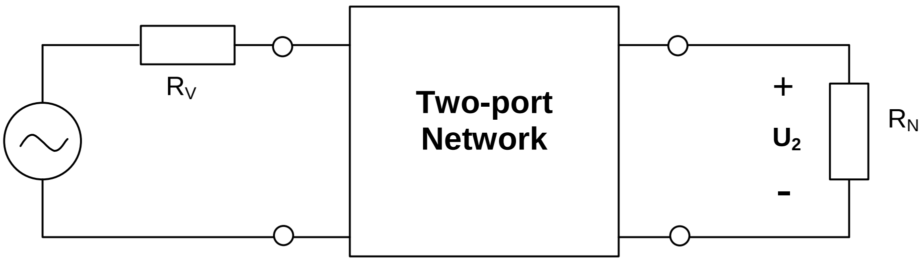


Figure E.2: Voltage across the load with a two-port network inserted

These quantities are directly related to the scattering parameters associated with the two-port network as defined in clause E.2:

- Transmission Function = s_{21} Magnitude of Transmission Function (in dB) = 20 $\log_{10}(|s_{21}|)$
- Insertion Loss = $1/s_{21}$ Magnitude of Insertion Loss (in dB) = -20 $\log_{10}(|s_{21}|)$

E.2 Derivation of s-parameters from primary cable parameters

The testloops are defined by one or a cascade of cable sections. The characteristics of each section are specified by means of primary cable parameters $\{Z_s, Y_p\}$ per unit length (L_0). This clause gives the equations to evaluate the relevant characteristics of cable sections (s-parameters) from the primary parameters and to handle cascade of cable sections.

Insertion loss and return loss of a cable section, for SDSL, can be calculated from the primary parameters $\{Z_s, Y_p\}$ per unit length (L_0) by evaluating the two-port s-parameters, normalized to $\mathbf{R_N}$ = 135 Ω.

$Z_{sx} = (L/L_0) \cdot Z_s$	$\gamma_x = \sqrt{Z_{sx} \cdot Y_{px}}$	$\alpha_x = real(\gamma_x)$	$R_{sx} = real(Z_{sx})$	$G_{px} = real(Y_{px})$
$Y_{px} = (L/L_0) \cdot Y_p$	$Z_0 = \sqrt{Z_{sx} / Y_{px}}$	$\beta_x = imag(\gamma_x)$	$L_{sx} = imag(Z_{sx}/\omega)$	$C_{px} = imag(Y_{px}/\omega)$

$$S = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} = \frac{1}{(Z_0/R_v + R_v/Z_0) \cdot \tanh(\gamma_x) + 2} \times \begin{bmatrix} (Z_0/R_v - R_v/Z_0) \cdot \tanh(\gamma_x) & 2/\cosh(\gamma_x) \\ 2/\cosh(\gamma_x) & (Z_0/R_v - R_v/Z_0) \cdot \tanh(\gamma_x) \end{bmatrix}$$

Insertion Loss: $1/s_{21}$

Return Loss: $1/s_{11}$

The s-parameters of two cable sections (a and b) in cascade, $\mathbf{S}_{ab}$, can be calculated from the s-parameters $\mathbf{S}_a$ and $\mathbf{S}_b$ as described below:

$$S_{\mathbf{ab}} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} = \frac{1}{1 - s_{22a} \cdot s_{11b}} \cdot \begin{bmatrix} s_{11a} - \Delta_{sa} \cdot s_{11b} & s_{12b} \cdot s_{12a} \\ s_{21a} \cdot s_{21b} & s_{22b} - \Delta_{sb} \cdot s_{22a} \end{bmatrix} \Delta_{si} = s_{11i} \cdot s_{22i} - s_{12i} \cdot s_{21i}$$

Annex F (informative): Bibliography

- ETSI TS 101 388 (V1.1.1): "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Asymmetric digital subscriber line (ADSL) - Coexistence of ADSL and ISDN-BA on the same pair [ANSI T1.413 - 1998, modified]".

History

Document history		
V1.1.1	November 1998	Publication
V1.2.1	October 2001	Publication