ETSI TS 101 388 V1.3.1 (2002-05)

Technical Specification

Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Asymmetric Digital Subscriber Line (ADSL) - European specific requirements

[ITU-T Recommendation G.992.1 modified]

Reference

RTS/TM-06025

Keywords

access, ADSL, basic, endorsement, interaction, interworking, IP, ISDN, transmission

ETSI

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

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

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Important notice

Individual copies of the present document can be downloaded from:
http://www.etsi.org

The present document may be made available in more than one electronic version or in print. In any case of existing or perceived difference in contents between such versions, the reference version is the Portable Document Format (PDF). In case of dispute, the reference shall be the printing on ETSI printers of the PDF version kept on a specific network drive within ETSI Secretariat.

Users of the present document should be aware that the document may be subject to revision or change of status. Information on the current status of this and other ETSI documents is available at
http://portal.etsi.org/tb/status/status.asp

If you find errors in the present document, send your comment to:
editor@etsi.fr

Copyright Notification

Contents

Intellectual Property Rights

IPRs essential or potentially essential to the present document may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (http://webapp.etsi.org/IPR/home.asp).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Foreword

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

The present document, in conjunction with ITU-T Recommendation G.992.1 [2] provides the European specifications for ADSL.

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 together with the addition of 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 base band 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 (V1.3.2): "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): "Asymmetrical digital subscriber line (ADSL) transceivers".

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

[4] ITU-T Recommendation G.996.1 (2001): "Test procedures for digital subscriber line (DSL) transceivers".

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

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

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

[8] ETSI TS 101 952-1-3: "Access network xDSL transmission filters; Part 1: ADSL splitters for European deployment; Sub-part 3: Specification of ADSL/ISDN splitters".

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

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: 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: 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: EC ADSL over ISDN systems are configured as described in annex B of ITU-T Recommendation G.992.1 [2].

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

NOTE: EC ADSL over POTS systems are configured as described for overlapped PSD masks in annex A of ITU-T Recommendation G.992.1 [2].

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: FDD ADSL over ISDN systems are configured as described in annex B of ITU-T Recommendation G.992.1 [2], 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: FDD ADSL over POTS systems are configured as described in annex A of ITU-T Recommendation G.992.1 [2].

reference impedance (R_N): chosen impedance used for specifying transmission and reflection characteristics of cables and test loops

NOTE: 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.

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

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
ADL	All Digital Loop
ADSL	Asymmetric 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
AWGN	Additive White Gaussian Noise
BER	Bit Error Ratio
EC	Echo Cancelled
FDD	Frequency Division Duplexing/Duplexed
FEXT	Far-End Cross-Talk
IDFT	Inverse Discrete Fourier Transform
ISDN	Integrated Services Digital Network
ISDN-BA	Integrated Service Digital Network Basic Rate Access
LTU	Line Termination Unit
NEXT	Near-End Cross-Talk
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 version 1.1.1 of the present document [3] (version 1.1.1 was based on ANSI T1.413 [5]).

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.

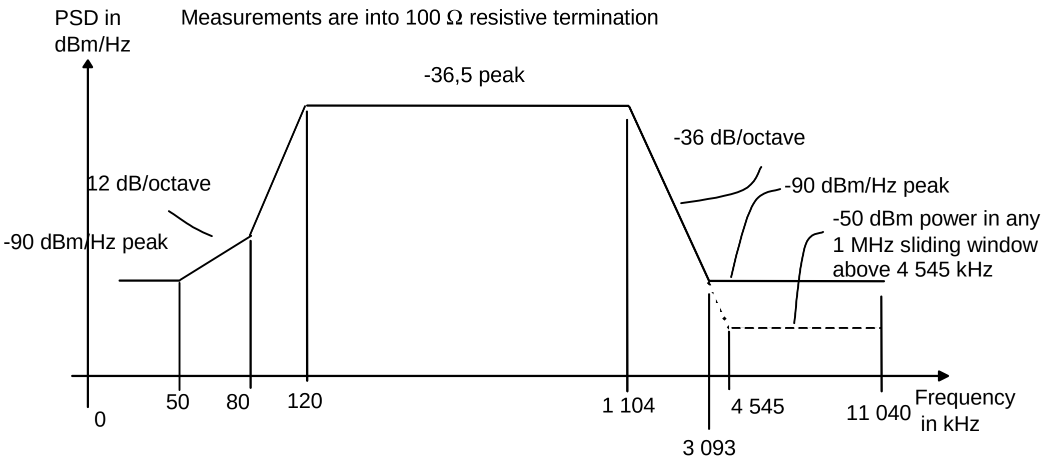
All PSD measurements made at the Line port of the ISDN splitter shall measure the spectral power into a resistive load having the same value as the design impedance for ADSL (R_V = 100 Ω).

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.

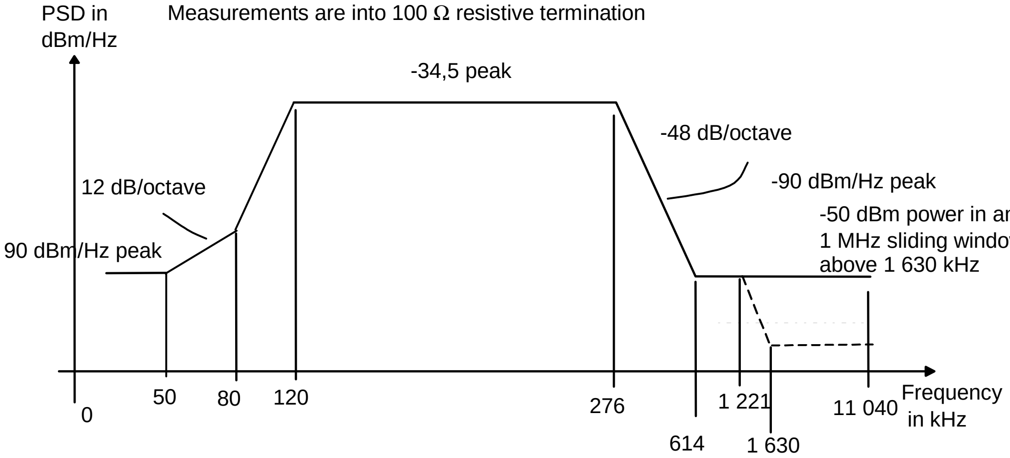
Figure 1: ATU-C transmitted PSD mask

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

Frequency band (kHz)	Equation for line (dBm/Hz)
$0 \leq f \leq 50$	-90
$50 < f \leq 80$	$-90 + 12 \times \log_2(f/50)$
$80 < f \leq 120$	$-81,8 + 77,4 \times \log_2(f/80)$
$120 < f \leq 1\,104$	-36,5
$1\,104 < f \leq 3\,093$	$-36,5 - 36 \times \log_2(f/1\,104)$
$3\,093 < f \leq 4\,545$	-90 peak, with maximum power in the [f, f + 1 MHz] window of $(-36,5 - 36 \times \log_2(f/1\,104) + 60)$ dBm
$4\,545 < f \leq 11\,040$	-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 ≤ 50	-90
50 < f ≤ 80	-90 + 12 x $\log_2$(f/50)
80 < f ≤ 120	-81,8 + 80,9 x $\log_2$(f/80)
120 < f ≤ 276	-34,5
276 < f ≤ 614	-34,5 - 48 x $\log_2$(f/276)
614 < f ≤ 1 221	-90
1 221 < f ≤ 1 630	-90 peak, with maximum power in the [f, f + 1 MHz] window of (-90 - 48 x $\log_2$(f/1 221) + 60) dBm
1 630 < f ≤ 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.

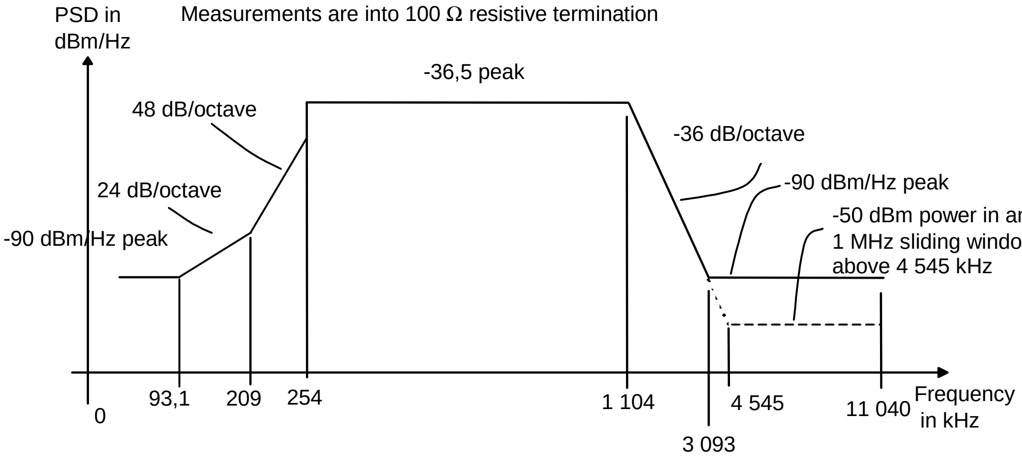
All PSD measurements made at the Line port of the ISDN splitter shall measure the spectral power into a resistive load having the same value as the design impedance for ADSL (R_V = 100 Ω).

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 ITU-T Recommendation 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 be sufficient to fulfil the requirements for the radiation power limits specified by national frequency management entities.

5 Transmission performance objectives and test methods

This clause defines the transmission performance objectives and laboratory test methods to stress ADSL transceivers The test methods are intended to be representative of a high-penetration scenario in access networks. This high-penetration approach enables operators to define deployment rules that apply across a wide range of operational situations. The noise models represent a mixture of different DSL services (including some systems that may need repeaters in real deployment) that are assumed to share the same cable with the transceiver under test. For the sake of simplicity and reproducibility, the noise models do not take into account reach limitations of some of the DSL services assumed in the noise models.

The performance objectives are only intended for the purpose of testing ADSL transceivers and should not be considered a limitation on deployment in operator networks. 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 and ADSL over ISDN operations (see ITU-T Recommendation G.992.1 [2]). The design impedance $\mathbf{R_V}$ is 100 Ω. In the context of the present document all spectra represent single-sided Power Spectral Densities (PSDs).

5.1 Test procedures

This clause provides a 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 cross-talk noise or impulse noise. This noise margin indicates what increase of cross-talk noise or impulse noise level can be tolerated by the ADSL system under test before the bit error ratio exceeds the design target.

5.1.1 Test set-up definition

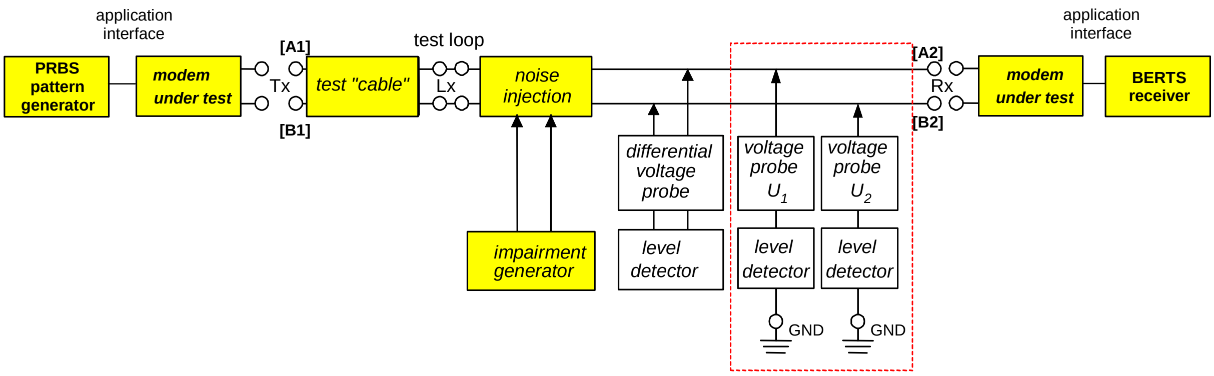
Figure 4 illustrates the functional description of the test set-up. It includes:

- 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 entire 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 entire 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. In these external splitters an optional highpass can be present. However, when measuring the performance requirements of clause 5.5, the external highpass should be limited to the DC blocking variant, composed of 2 series capacitors, because the higher order variant is still under study. Moreover, the ADSL transceiver variant used with the DC blocking capacitors should be a version compensating the series capacitors.

NOTE 3: The management system should be connected to enable collection of parameters from the OAM facilities, in particular loop loss and SNR figures.

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_{inj} shall have a value of $|Z_{inj}| > 4$ kΩ in the frequency range from 100 Hz to 2 MHz.

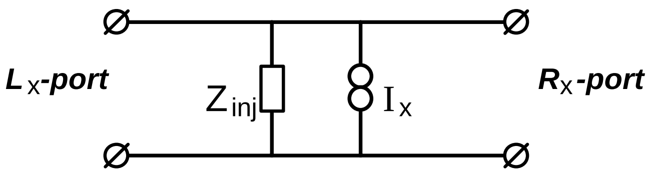


Figure 5: Norton equivalent circuit diagram for the differential mode noise injection

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. 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, results in 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 differential mode noise injection is calibrated using the configuration shown in figure 6. During calibration the R_x side of the noise injector is terminated by the design impedance $\mathbf{R_V}$ (= 100 Ω) and the L_X side of the noise injector is terminated by an impedance Z_{Lx}. The noise levels given in clause 5.3 specify the PSD dissipated in $\mathbf{R_V}$ on the R_X side when Z_{Lx} on the L_x side is equal to the calibration impedance Z_{cal}. The impedance Z_{cal} is defined in figure 7.

NOTE: This noise injection method is similar to the cross-talk injection method specified in ITU-T Recommendation G.996.1 (G.test) [4], clause 5.1.2.1.

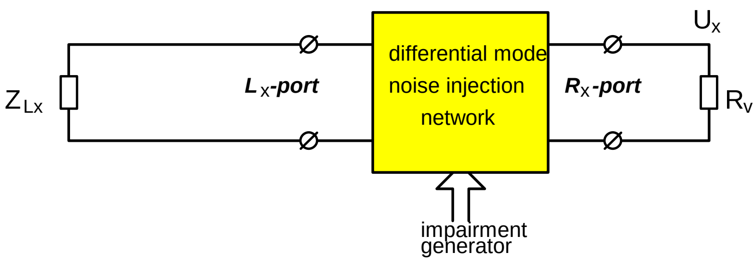


Figure 6: Configuration for noise level calibration

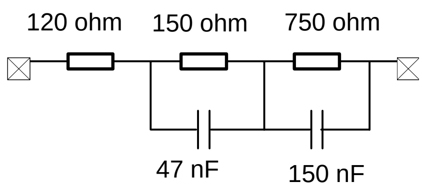


Figure 7: Calibration impedance Z_{cal}

ΩIf the impedance Z_{Lx} on the L_x side of the noise injection circuit is equal to the calibration impedance Z_{cal} as given in figure 7, then the PSD dissipated in the impedance R_v shall be equal to the noise PSD $P_{xn}(f)$ defined in clause 5.3.1. For an arbitrary value of the impedance Z_{Lx}, the PSD dissipated in R_v is equal to:

$$P_{cal}(f) = G(f, Z_{Lx}) P_{xn}(f).$$

The impedance dependent correction factor is specified as:

$$G(f, Z_{Lx}) = \left| \frac{\frac{1}{Z_{Lx}} + \frac{1}{Z_{inj}} + \frac{1}{R_v}}{\frac{1}{Z_{cal}} + \frac{1}{Z_{inj}} + \frac{1}{R_v}} \right|^2 ,$$

where Z_{cal} is the calibration impedance given in figure 7, Z_{inj} is the Norton equivalent impedance of the noise injection circuit (see figure 5), and R_v = 100 Ω is the ADSL design impedance.

The noise generator gain settings determined during calibration shall be used during performance testing. During performance testing the noise injection circuit will be inserted as shown in figure 4. Because the loop impedance and the impedance of the modem under test may differ from the impedances Z_{Lx} and R_v used during calibration, the voltage over the Rx port of the modem may differ from the voltage U_x observed during calibration.

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 8 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 8 are an artificial mixture of cable sections. A number of different loops have been constructed to capture a wide range of cable impedances, and to represent ripple in the amplitude and phase characteristics of the test loop 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 test loops with highly mismatched cable sections.

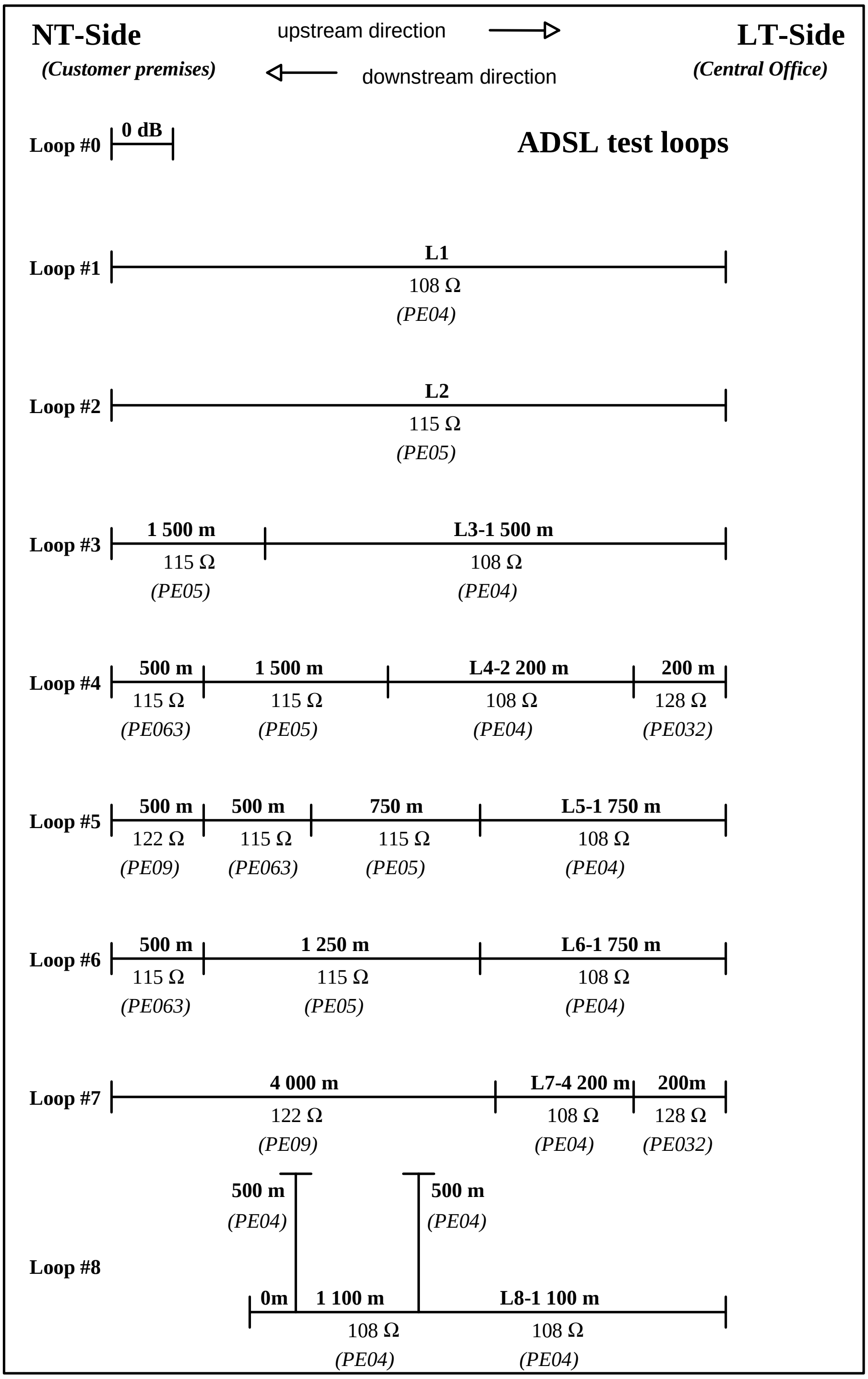
- One test loop includes bridged taps, which cause rapid variations in amplitude and phase characteristics of the cable transmission function. In some European access networks, installation practices have introduced bridged taps in the past. The presence of the bridged tap stresses the ADSL modem under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

The topology of the test loops is specified in figure 8. 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 8 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 for each of the tests.



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 8: ADSL test loop topology

5.2.3 Test loop accuracy

The different cable sections of the test loops shown in figure 8 are specified by two-port cable models that represent real twisted pair cables. Cable simulators as well as real cables can be used to construct 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 20 kHz and 1,8 MHz.

- The magnitude of the test loop characteristic impedance shall approximate the characteristic impedance of the specified models within ±7 % on a linear scale, between 20 kHz and 1,8 MHz.

- The group delay of the test loop shall approximate the group delay of the specified cascaded models within ±3 % on a linear scale, between 20 kHz and 1,8 MHz.

The *electrical* lengths (insertion loss at specified test frequency) of the test loops, 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 adjusted 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 9 shows 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 eight impairment generators G1 to G8 generate noise as defined in clauses 5.3.3.1 to 5.3.3.8. Their noise characteristics are independent of the test loops and bit-rates.

- The NEXT coupling function $H_1(f, L)$ models the loop length dependency 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.

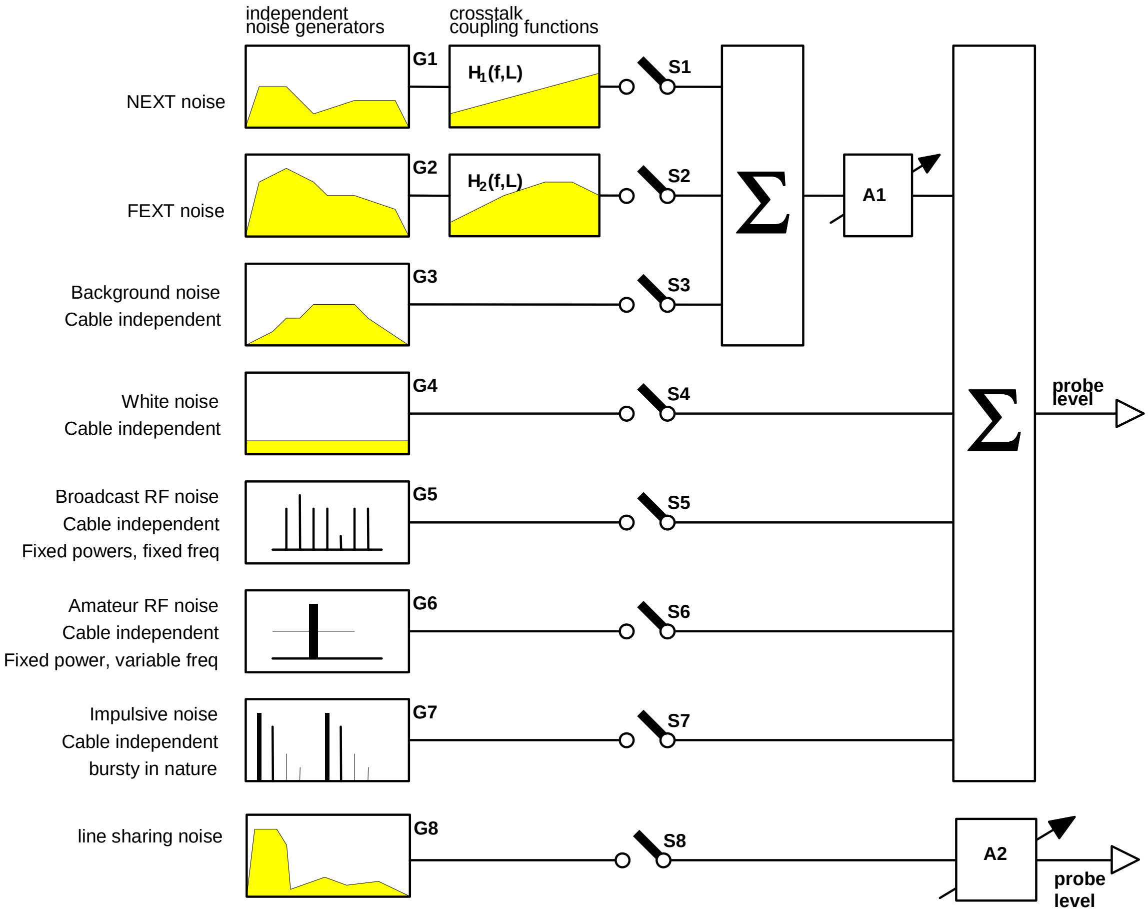
- The FEXT coupling function $H_2(f, L)$ models the loop length dependency and frequency dependency of the FEXT impairment, as specified in clause 5.3.2. The FEXT coupling function is independent of the test loop topology, but depends on the length of the test loop. The FEXT coupling function is defined in table 5.

- Switches S1-S7 are logocal switches that indicate 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.

- Amplifier A2 models the ability to increase the noise level of generator G8. Unless otherwise specified, the gain of A2 is set to 0 dB.

The diagram in figure 9 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 9. 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: 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.

NOTE 3: 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 9: Functional diagram of the composition of the impairment noise

This functional diagram will be used for impairment tests in the downstream and upstream directions. 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 description of a noise PSD. 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, the eight individual impairment generators G1 to G8 can represent different values for each noise model. 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.

Generator G1-G3 represent cross-talk noise and G4 a noise floor. G1 represent the cumulated noise from all collocated disturbers at one end of the loop near to the receiver under test. G2 represent the same, but located at another end of the loop far from the receiver under test. Generator G3 represent all cumulated noise from disturbers at unidentified locations. Generator G4 is a white noise generator to provide designers of noise generation equipment a reasonable noise floor to avoid over-design of their equipment.

The spectral power $P_{xn}(f)$ for cross-talk noise is characterized by the sum:

$$P_{xn}(f) = |A1|^2 \times \{ |H_1(f,L)|^2 \times P_{G1}(f) + |H_2(f,L)|^2 \times P_{G2}(f) + P_{G3}(f) \} + P_{G4}(f)$$

Each component of this sum is specified in the following clauses. Only the noise generators that are active during testing should be included during calibration. 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.

Generators G5 and G6 represent ingress noise. The level of the ingress noise and the calibration of noise sources G5 and G6 are for further study.

Generator G7 represents impulse noise. The definition of signals for G7 is for further study.

Generator G8 represents energy appearing at the receiver of the unit under test due to signals sharing the line.

5.3.2 Cable cross-talk models

The purpose of the cable cross-talk models is to model both the length and frequency dependence of cross-talk measured in real cables. The cross-talk coupling functions, $H_1(f,L)$ and $H_2(f,L)$, are transfer functions that adjust the levels of the noise generators in figure 9 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 B and the cable characteristics of annex A. Values of the required electrical lengths and the corresponding (informative) physical lengths are summarized in table 20 through table 51 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 B 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 cross-talk 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 originated 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 cross-talk 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 originated 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 generators G1 and G2.

Table 5: Definition of the cross-talk coupling functions

$H_1(f, L) = K_{xn} \times (f/f_0)^{0,75} \times \sqrt{1 - |s_{T0}(f, L)|^4}$ $H_2(f, L) = K_{xf} \times (f/f_0) \times \sqrt{(L/L_0)} \times |s_{T0}(f, L)|$
$K_{xn} = 10^{(-50/20)} \approx 0{,}0032$, $f_0 = 1$ 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 cross-talk noise from a predominantly near-end origin. This noise, filtered by the NEXT cross-talk 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 "FA", "FB", "FC" or "FD".
- Symbol "X.LT.#" and "X.NT.#" refers to the cross-talk profiles, as defined in clause 5.3.4.1.

The G1 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 cross-talk noise from a predominantly far-end origin. This noise, filtered by the FEXT cross-talk 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 "FA", "FB", "FC" or "FD".
- Symbol "X.LT.#" and "X.NT.#" refers to the cross-talk 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.

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 differential 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 should be as 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 than 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 should be as 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 with a 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

Frequency (kHz)	99	207	333	387	531	603	711	801	909	981
Differential mode power (dBm)	–58	–43	–50	–54	–59	–60	–57	–62	–52	–63
Common mode power (dBm)	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
NOTE: The frequencies and power levels are tentative and should be revised in the future based on additional measurements. Different power levels may be appropriate for ATU-C and ATU-R. A long term goal is to align the RFI frequency and power levels specified for ADSL, SDSL and VDSL.										

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 cross-talk 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 5 μs, and it shall be applied to the line at a frequency of once per second.

5.3.3.8 Line sharing noise generator [G8]

Noise generator G8 represents the impairment that originates from ISDN systems sharing the same wire pair as used by the ADSL (over ISDN) systems. Noise generator G8 is only used for testing of ADSL over ISDN systems and shall not be active when ADSL over POTS systems are tested.

Table 7 specifies the break points for the PSD for noise generator G8. The PSD profiles for noise generator G8 are constructed with straight lines between these break points, when plotted against a logarithmic frequency scale and a linear dBm scale.

The electrical characteristics of the injection circuit for noise generator G8 are for further study. Annex F provides an example injection method that can be used for noise generator G8.

NOTE: The specification of the injection circuit for noise generator G8 may affect the performance objectives specified in clause 5.5.

Table 7: Break points of the PSD masks for noise generator G8

f (kHz)	PSD (dBm/Hz)
5	-48,7
22,5	-44,7
40	-45,3
65	-47,4
80	-50,1
100	-59,5
122,5	-108,5
154,5	-126,1
170	-127
185	-131
200	-135
215	-140
> 215	< -140

5.3.4 Profiles of the individual impairment generators

5.3.4.1 Frequency domain profiles of generators G1 and G2

Cross-talk 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 cross-talk noise has been partitioned into smaller, more easily specified components. Noise generators 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 9) 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 generated for the FDD versions of ADSL, the PSD values of one type of these disturbers had changed slightly compared to the values used to generate noise PSDs for the EC version of ADSL.

The character "#" is used as a placeholder for the letters "FA", "FB","FC", and "FD", which indicate the noise model.

Four noise models have been defined for ADSL tests:

- **Type "FA" 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 "FB" 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 "FC" 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 "FB".
- **Type "FD" models** are intended to represent a ***pure self-cross-talk 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 8 and the NT-profiles in table 9. Each PSD profile specifies the maximum available spectral power of an equivalent disturber that represents a mix of disturbers. 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 8: Break frequencies of the "X.LT.#" PSD masks for testing EC ADSL over POTS systems

X.LT.FA (Hz)	(dBm/Hz)	X.LT.FB (Hz)	(dBm/Hz)	X.LT.FC (Hz)	(dBm/Hz)	X.LT.FD (Hz)	(dBm/Hz)
0	-20,0	0	-25,6	0	-25,6	0,0	-87,4
15 k	-20,0	15 k	-25,6	15 k	-25,6	3,99 k	-87,4
31 k	-21,5	31 k	-27,0	31 k	-27,0	4 k	-82,4
63 k	-25,6	63 k	-31,3	63 k	-31,3	25,875 k	-29,4
112 k	-25,7	112 k	-31,3	112 k	-31,3	1,104 M	-29,4
204 k	-26,1	204 k	-31,8	204 k	-31,8	3,093 M	-79,9
298 k	-26,6	298 k	-32,5	298 k	-32,5	4,545 M	-99,9
420 k	-27,3	420 k	-33,7	420 k	-33,7	30 M	-99,9
1,104 M	-27,3	1,104 M	-33,7	1,104 M	-33,7		
4,5 M	-97,8	4,5 M	-104,1	1,85 M	-58,1		
30 M	-97,8	30 M	-104,1	23 M	-104,1		
				30 M	-104,1		

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

X.NT.FA (Hz)	(dBm/Hz)	X.NT.FB (Hz)	(dBm/Hz)	X.NT.FC (Hz)	(dBm/Hz)	X.NT.FD (Hz)	(dBm/Hz)
0	-20,0	0	-25,6	0	-25,6	0	-87,4
15 k	-20,0	15 k	-25,6	15 k	-25,6	3,99 k	-87,4
22 k	-20,8	22 k	-26,6	22 k	-26,6	4 k	-82,4
29 k	-20,8	29 k	-26,6	29 k	-26,6	25,875 k	-27,4
61 k	-24,4	61 k	-30,3	61 k	-30,3	138 k	-27,4
138 k	-24,5	138 k	-30,4	138 k	-30,4	307 k	-79,9
153 k	-28,2	153 k	-33,2	153 k	-33,2	1,221 M	-79,9
220 k	-28,9	220 k	-33,9	220 k	-33,9	1,63 M	-99,9
315 k	-30,8	315 k	-35,5	315 k	-35,5	30 M	-99,9
387 k	-34,6	387 k	-39,5	387 k	-39,5		
461 k	-43,4	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 k	-45,5		
1,2 M	-75,3	1,2 M	-82,0	1,41 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		

5.3.4.1.2 Frequency domain profiles for EC ADSL over ISDN

The LT-profiles for EC ADSL over ISDN systems are specified in table 10 and the NT-profiles in table 11. 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 10: Break frequencies of the "X.LT.#" PSD masks for testing EC ADSL over ISDN systems

X.LT.FA (Hz)	(dBm/Hz)	X.LT.FB (Hz)	(dBm/Hz)	X.LT.FC (Hz)	(dBm/Hz)	X.LT.FD (Hz)	(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	-21,5	30 k	-27,2	30 k	-27,2	80 k	-71,8
66 k	-27,7	66 k	-32,6	66 k	-32,6	138 k	-29,4
130 k	-27,7	130 k	-32,7	130 k	-32,7	1,104 M	-29,4
138 k	-25,9	138 k	-31,5	138 k	-31,5	3,093 M	-79,9
204 k	-26,1	204 k	-31,8	204 k	-31,8	4,545 M	-99,9
298 k	-26,6	298 k	-32,5	298 k	-32,5	30 M	-99,9
420 k	-27,3	420 k	-33,7	420 k	-33,7		
1,104 M	-27,3	1,104 M	-33,7	1,104 M	-33,7		
4,5 M	-97,8	4,5 M	-104,1	1,85 M	-58,1		
30	-97,8	30 M	-104,1	23 M	-104,1		
				30 M	-104,1		

Table 11: Break frequencies of the "X.NT.#" PSD masks for testing EC ADSL over ISDN systems

X.NT.FA (Hz)	(dBm/Hz)	X.NT.FB (Hz)	(dBm/Hz)	X.NT.FC (Hz)	(dBm/Hz)	X.NT.FD (Hz)	(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 12 and the NT-profiles in table 13. 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 12: Break frequencies of the "X.LT.#" PSD masks for testing FDD ADSL over POTS systems

X.LT.FA (Hz)	(dBm/Hz)	X.LT.FB (Hz)	(dBm/Hz)	X.LT.FC (Hz)	(dBm/Hz)	X.LT.FD (Hz)	(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 13: Break frequencies of the "X.NT.#" PSD masks for testing FDD ADSL over POTS systems

X.NT.FA (Hz)	(dBm/Hz)	X.NT.FB (Hz)	(dBm/Hz)	X.NT.FC (Hz)	(dBm/Hz)	X.NT.FD (Hz)	(dBm/Hz)
1	-20,0	1	-25,8	1	-25,8	1	-87,4
15 k	-20,0	15 k	-25,6	2 k	-25,8	3,99 k	-87,4
24 k	-20,9	24 k	-26,5	15 k	-25,6	4 k	-82,4
30 k	-21,0	30 k	-26,8	22 k	-26,4	25,875 k	-27,9
45 k	-23,0	61 k	-30,5	30 k	-26,8	138 k	-27,9
60 k	-24,7	138 k	-30,8	45 k	-28,8	307 k	-79,9
138 k	-24,9	149 k	-33,0	60 k	-30,5	1 221 k	-79,9
151 k	-28,0	200 k	-33,5	138 k	-30,7	1 630 k	-99,9
207 k	-28,7	308 k	-35,2	150 k	-33,0	30 M	-99,9
300 k	-30,3	375 k	-38,5	206 k	-33,6		
358 k	-32,8	456 k	-46,9	338 k	-35,7		
407 k	-36,7	605 k	-68,4	477 k	-47,8		
500 k	-48,6	755 k	-68,4	788 k	-45,4		
594 k	-62,3	980 k	-77,3	1 064 k	-45,5		
755 k	-62,3	1 128 k	-80,8	1 500 k	-50,1		
1 059 k	-73,7	1 402 k	-83,7	1 800 k	-58,6		
1 221 k	-75,5	2 570 k	-101,6	20 M	-101,6		
1 400 k	-77,9	30 M	-101,6	30 M	-101,6		
2 532 k	-96,2						
30 M	-96,2						

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 14 and the NT-profiles in table 15. 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 14: Break frequencies of the "X.LT.#" PSD masks for testing FDD ADSL over ISDN systems

X.LT.FA (Hz)	(dBm/Hz)	X.LT.FB (Hz)	(dBm/Hz)	X.LT.FC (Hz)	(dBm/Hz)	X.LT.FD (Hz)	(dBm/Hz)
1	-20,1	1	-25,8	1	-25,7	1	-79,9
14 k	-20	2 k	-25,8	15 k	-25,6	93,1 k	-79,9
30 k	-21,5	15 k	-25,6	30 k	-27,2	209 k	-51,9
45 k	-24,1	30 k	-27,1	45 k	-29,6	253,99 k	-38,4
64 k	-27,7	45 k	-29,6	62 k	-32,6	254 k	-29,9
105 k	-27,6	66 k	-32,6	107 k	-32,6	1 104 k	-29,9
204 k	-28,7	106 k	-32,6	203 k	-33,6	3 093 k	-79,9
253 k	-29,4	200 k	-33,6	253,8 k	-34,3	4 545 k	-99,9
255 k	-26,7	253 k	-34,3	254 k	-32,5	30 M	-99,9
412 k	-27,8	254 k	-32,5	300 k	-32,8		
1 104 k	-27,8	303 k	-32,9	409 k	-34,2		
4 543 k	-96,2	417 k	-34,2	1 104 k	-34,2		
30 M	-96,2	1 104 k	-34,2	1 703 k	-53,6		
		4 439 k	-101,6	2 162 k	-66,2		
		30 M	-101,6	2 387 k	-63,7		
				2 520 k	-63,6		
				2 677 k	-65,5		
				20 M	-101,6		
				30 M	-101,6		

Table 15: Break frequencies of the "X.NT.#" PSD masks for testing FDD ADSL over ISDN systems

X.NT.FA (Hz)	(dBm/Hz)	X.NT.FB (Hz)	(dBm/Hz)	X.NT.FC (Hz)	(dBm/Hz)	X.NT.FD (Hz)	(dBm/Hz)
1	-20,1	1	-25,8	1	-25,6	1	-79,9
15 k	-20	2 k	-25,8	15 k	-25,6	50 k	-79,9
30 k	-21,5	15 k	-25,6	30 k	-27,2	80 k	-71,8
45 k	-24,1	30 k	-27,1	45 k	-29,6	120 k	-27,9
65 k	-27,6	44 k	-29,6	62 k	-32,6	276 k	-27,9
111 k	-27,7	64 k	-32,6	114 k	-32,7	614 k	-79,9
120 k	-24,8	114 k	-32,6	120 k	-30,7	1 221 k	-79,9
275 k	-25,3	120 k	-30,7	200 k	-31,0	1 630 k	-99,9
300 k	-29,1	277 k	-31,4	276 k	-31,4	30 M	-99,9
403 k	-36	305 k	-34,9	300 k	-34,6		
500 k	-48,6	389 k	-39,3	377 k	-38,7		
614 k	-64,8	500 k	-53,6	470 k	-47,8		
630 k	-64,8	620 k	-70,1	802 k	-45,4		
651 k	-62,3	633 k	-70,1	1 024 k	-45,6		
755 k	-62,4	650 k	-68,2	1 309 k	-47,8		
1 023 k	-72,7	758 k	-68,5	1 587 k	-52,3		
1 220 k	-75,5	1 071 k	-79,9	1 900 k	-63,0		
1 400 k	-77,9	1 222 k	-81,6	2 011 k	-76,8		
2 590 k	-96,2	1 398 k	-83,7	2 283 k	-63,7		
30 M	-96,2	2 479 k	-101,6	2 492 k	-63,7		
		30 M	-101,6	2 716 k	-66,1		
				20 M	-101,6		
				30 M	-101,6		

5.3.4.2 Time domain profiles of generator G1-G4

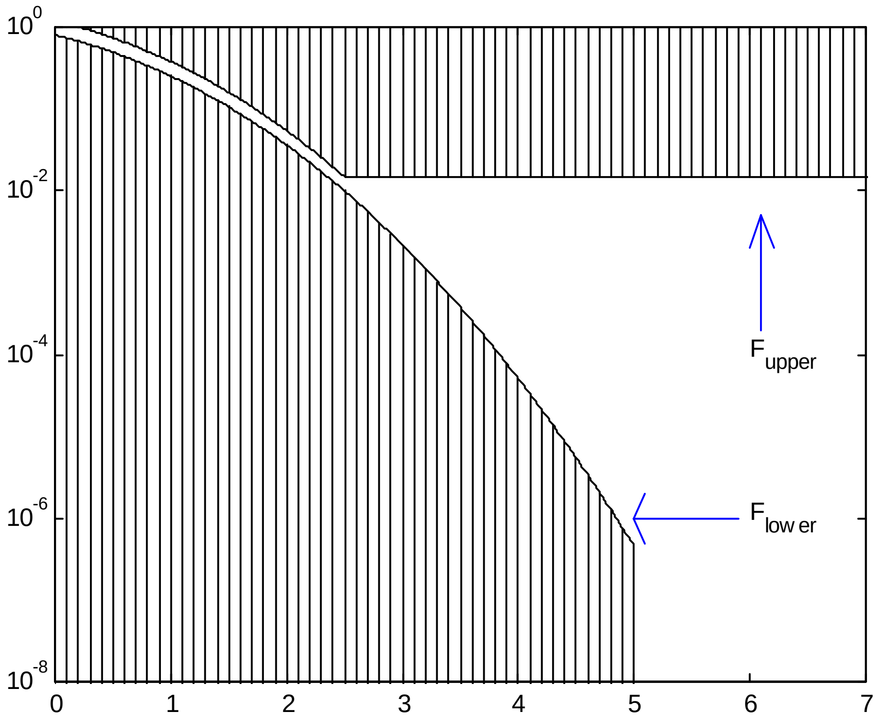
The noise, as specified in the frequency domain in clauses 5.3.3.1 to 5.3.3.4, shall be random in nature and near Gaussian distributed. This means that the amplitude distribution function of the combined impairment noise injected at the adding element (see figure 4) shall lie between the two boundaries illustrated in figure 10 and defined in table 16.

It is expected that noise generators will generate signals that are approximately Gaussian. Therefore, the upper bound of figure 10 is loose. PDFs of signals generated by noise generators are expected to be well below the upper bound allowed by the PDF mask shown in figure 10.

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).



NOTE: The non-shaded area is the allowed region. The boundaries of the mask are specified in table 16.

Figure 10: Mask for the amplitude distribution function.

Table 16: 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 16 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 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 long-term bit error ratio shall be less than 1 in 10^7, with margin greater than 0 dB. In general, the bit error ratio, and the frequency of error bursts should decrease as the margin is increased. The behaviour of the bit error ratio with increasing noise margin depends on the modem settings (e.g. interleaver settings).

NOTE: The specification of performance objectives for error performance with margins equal to or greater than 6 dB, including performance objectives for the frequency of error bursts and measuring methods to establish conformance to these limits with necessary confidence, is for further study.

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 h to ensure long-term temporal stability (see clause 5.4.3).

5.4.1.1 Control of transmit power in opposing direction

This clause specifies the transmit PSD and the bitrate to be used in the direction opposing the direction under test.

The transmit PSD used in the direction not under test shall be at the nominal value. This means that the transmit PSD shall be around -40 dBm/Hz minus the power cutback in downstream, and around -38 dBm/Hz in upstream. The individual carrier gains shall be ±2,5 dB around the nominal. The bitrate of the link in the direction not under test shall be at the maximal available value, with a target margin of 6 dB. Tones determined to be unusable in the bit-loading procedure are allowed to be turned off.

NOTE: With these conditions, a maximal number of tones will be used in the direction not under test, all with margin of about 6 dB, all around the nominal PSD. The PSD level can be forced around the nominal level by forcing the noise margin to highest possible value via the appropriate interface of the modem.

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 cross-talk noise margin

To measure the cross-talk noise margin, the cross-talk noise level **x** is increased in steps of 1 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 9, equally over the full frequency band of the ADSL system under test. The cross-talk noise margin is defined as the highest increase in noise level, relative to the 0 dB level, that yields a BER no higher than 10^{-7}.

A delay of 5 seconds shall be imposed between 1 dB increases to allow the system to stabilize.

The noise margins shall be measured for upstream as well as downstream transmission for all the test loops defined in clause 5.2 except loop #0, the zero length loop. To verify that ADSL systems under test meet the 6 dB cross-talk noise margin requirement, it is sufficient to verify that the BER is no higher than 10^{-7} when the noise level is increased by 6 dB, in steps of 1 dB, relative to the 0 dB 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 through a mandatory subset of all possible performance tests described in the present document. Table 17 specifies these mandatory conformance tests for downstream transmission, and table 18 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 cross-talk noise is injected, while in group 2 a combination of cross-talk noise and ingress noise is injected. Group 2 is associated with a modified (shorter) reach requirement.

NOTE: The reach requirements for group 2 of the conformance tests (R2) are for further study. It is expected that the reach under the condition of cross-talk noise plus ingress noise will be shorter than the reach under the condition of cross-talk noise without ingress noise.

Table 17: Test matrix for downstream conformance testing, defining the composition of test loops and noise models that are to be used for various downstream bit rates

Group	Bit rate kbit/s	Test loops	G1.DN.# (#=model)	G2.DN.# (#=model)	G3	G4	G5	G6	G7	G8	Reach	Number of tests
1	**512**	0,1-8	FA, FB, FC, FD	FA, FB, FC, FD	-	×	-	-	-	-	R1.d	36
	1 024	0,1-8	FA, FB, FC, FD	FA, FB, FC, FD	-	×	-	-	-	-	R1.d	36
	2 048	0,1-8	FA, FB, FC, FD	FA, FB, FC, FD	-	×	-	-	-	-	R1.d	36
	6 144	0,1-8	FA, FB, FC, FD	FA, FB, FC, FD	-	×	-	-	-	-	R1.d	36
2	**512**	1,7	FA, FB	FA, FB	-	×	×	-	-	-	R2.d	4
	1 024	1,7	FA, FB	FA, FB	-	×	×	-	-	-	R2.d	4
	2 048	1,7	FA, FB	FA, FB	-	×	×	-	-	-	R2.d	4
	6 144	1,7	FA, FB	FA, FB	-	×	×	-	-	-	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 group 1 downstream performance objectives, specified in clause 5.5;

R2.d means the group 2 downstream performance objectives, specified in clause 5.5.

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

Table 18: Test matrix for upstream conformance testing, defining the composition of test loops and noise models that are to be used for various upstream bit rates

Group	Bit rate kbit/s	Test loops	G1.UP.# (#=model)	G2.UP.# (#=model)	G3	G4	G5	G6	G7	G8	Reach	Number of tests
1	**64**	0,1-8	FA, FB, FC, FD	FA, FB, FC, FD	-	×	-	-	-	-	R1.u	36
	256	0,1-8	FA, FB, FC, FD	FA, FB, FC, FD	-	×	-	-	-	-	R1.u	36
	640	0,1-8	FA, FB, FC, FD	FA, FB, FC, FD	-	×	-	-	-	-	R1.u	36
2	**64**	1,7	FA, FB	FA, FB	-	×	×	-	-	-	R2.u	4
	256	1,7	FA, FB	FA, FB	-	×	×	-	-	-	R2.u	4
	640	1,7	FA, FB	FA, FB	-	×	×	-	-	-	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 group 1 upstream performance objectives, specified in clause 5.5;

R2.u means the group 2 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 of caution related to the duration of the test: 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, even though 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 are specified in tables 20 through 51. 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 ratio. This value is bit rate dependent: the higher the payload bit rate, the lower 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.

Clauses 5.5.1 through 5.5.4 provide performance objectives for the ADSL variants, including EC ADSL over ISDN, EC ADSL over POTS, FDD ADSL over ISDN, and FDD ADSL over POTS.

The performance objectives shall be met while maintaining a 6 dB noise margin and a bit error ratio of 10^{-7} or lower.

Systems configured as specified in table 19 should meet the performance objectives. Other modem configuration parameter combinations may also result in the system meeting the objectives.

NOTE: The requirements in tables 20 through 51 were derived based on simulations. Following tests of real modems, in the future the requirements may need to be adjusted if specific requirements appear to be too high or too low for practical implementations.

Table 19: Modem configuration parameters for performance verification

Parameter	Value
Path	Interleaved
Latency	High
Trellis	To meet the objectives, trellis coding, which is an optional feature, may be used
Noise margin	6 dB

5.5.1 Performance objectives for EC ADSL over ISDN

Tables 20 through 27 provide performance objectives for EC ADSL over ISDN with noise models FA through FD. Systems configured as specified in table 19 should meet these performance objectives.

Table 20: Reach requirements for EC ADSL over ISDN downstream with noise model FA

Payload Bitrate (kbit/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	37,00* (2 594)	37,00 (3 459)	37,50* (3 004)	37,00* (3 135)	37,50 (3 306)	37,50 (3 144)	36,50 (4 810)	40,00* (2 143)
768	300	37,00* (2 594)	36,00 (3 366)	37,00 (2 969)	36,50 (3 099)	36,50 (3 236)	37,00 (3 109)	35,50 (4 740)	40,00* (2 143)
1 024	300	37,00* (2 594)	35,50 (3 319)	36,00 (2 899)	36,00 (3 064)	36,00 (3 201)	36,00 (3 039)	35,00 (4 704)	40,00* (2 143)
1 544	300	35,50 (2 489)	34,00 (3 179)	34,50 (2 794)	34,00 (2 924)	34,00 (3 061)	34,50 (2 934)	33,00 (4 564)	40,00* (2 143)
2 048	300	33,50 (2 349)	32,00 (2 992)	32,50 (2 653)	32,00 (2 784)	32,00 (2 920)	32,50 (2 793)	31,00 (4 424)	40,00* (2 143)
3 072	300	30,00 (2 103)	28,50 (2 664)	29,00 (2 408)	28,50 (2 538)	28,50 (2 674)	28,50 (2 512)	-	37,00 (1 934)
4 096	300	25,00 (1 752)	23,00 (2 149)	23,50 (2 021)	-	22,50 (2 253)	23,50 (2 162)	-	33,00 (1 653)
5 120	300	18,00 (1 260)	15,50 (1 447)	-	-	-	-	-	28,00 (1 314)
6 144	300	-	-	-	-	-	-	-	-
*	Limited in reach by longest reach in upstream direction.								

Table 21: Reach requirements for EC ADSL over ISDN upstream with noise model FA

Payload Bitrate (kbit/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	150	30,50 (2 582)	29,50 (3 610)	30,00 (3 002)	29,00 (3 117)	30,00 (3 338)	30,00 (3 170)	28,50 (4 944)	31,00 (2 146)
128	150	29,00 (2 455)	27,50 (3 366)	28,50 (2 876)	27,00 (2 949)	28,00 (3 169)	28,00 (3 001)	26,50 (4 776)	29,00 (1 977)
256	150	26,50 (2 244)	25,00 (3 060)	25,50 (2 622)	24,50 (2 737)	25,50 (2 958)	25,50 (2 790)	23,50 (4 516)	25,50 (1 676)
384	150	22,50 (1 907)	21,50 (2 632)	22,00 (2 327)	21,00 (2 441)	22,00 (2 663)	22,00 (2 495)	20,00 (4 236)	22,50 (1 439)
512	150	19,00 (1 611)	18,00 (2 204)	18,50 (2 030)	-	18,50 (2 367)	18,50 (2 198)	-	19,50 (1 146)
640	150	15,50 (1 316)	14,50 (1 776)	15,00 (1 738)	-	15,00 (2 072)	15,00 (1 907)	-	-
* Limited in reach by longest reach in downstream direction.									

Table 22: Reach requirements for EC ADSL over ISDN downstream with noise model FB

Payload Bitrate (kbit/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	43,00 (3 016)	41,50 (3 881)	42,50 (3 356)	42,00 (3 486)	42,00 (3 622)	42,50 (3 495)	41,50 (5 161)	46,50* (2 599)
768	300	42,00 (2 945)	40,00 (3 740)	41,00 (3 250)	41,00 (3 415)	40,50 (3 517)	41,00 (3 390)	40,00 (5 056)	46,50* (2 599)
1 024	300	41,00 (2 875)	39,00 (3 647)	40,00 (3 180)	40,00 (3 345)	40,00 (3 482)	40,00 (3 320)	39,00 (4 985)	46,50* (2 599)
1 544	300	39,50 (2 770)	38,00 (3 553)	39,00 (3 110)	38,50 (3 240)	38,50 (3 376)	38,50 (3 215)	37,50 (4 880)	46,50 (2 599)
2 048	300	38,00 (2 664)	36,00 (3 366)	37,00 (2 969)	36,50 (3 099)	36,50 (3 236)	36,50 (3 074)	36,00 (4 775)	44,50 (2 459)
3 072	300	35,00 (2 454)	33,50 (3 132)	34,00 (2 759)	33,50 (2 889)	33,50 (3 025)	34,00 (2 899)	32,50 (4 530)	41,50 (2 249)
4 096	300	31,50 (2 208)	30,00 (2 804)	30,50 (2 513)	30,00 (2 643)	30,00 (2 780)	30,00 (2 618)	28,50 (4 249)	38,00 (2 002)
5 120	300	27,00 (1 892)	25,50 (2 383)	26,00 (2 197)	25,50 (2 326)	25,00 (2 429)	25,50 (2 301)	-	35,00 (1 789)
6 144	300	21,00 (1 471)	19,50 (1 822)	20,00 (1 775)	-	18,50 (1 971)	19,50 (1 881)	-	30,50 (1 467)
* Limited in reach by longest reach in upstream direction.									

Table 23: Reach requirements for EC ADSL over ISDN upstream with noise model FB

Payload Bitrate (kbit/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	150	36,00 (3 046)	34,00* (4 160)	35,50 (3 467)	34,50 (3 581)	35,00 (3 760)	35,50 (3 635)	33,50* (5 365)	36,00 (2 567)
128	150	34,00 (2 878)	33,00 (4 038)	33,50 (3 298)	32,50 (3 413)	33,50 (3 634)	33,50 (3 466)	32,00 (5 238)	34,50 (2 439)
256	150	31,50 (2 666)	30,00 (3 671)	31,00 (3 087)	30,00 (3 201)	30,50 (3 380)	31,00 (3 255)	28,50 (4 944)	31,00 (2 146)
384	150	28,00 (2 371)	26,50 (3 243)	27,50 (2 791)	26,50 (2 907)	27,00 (3 085)	27,00 (2 917)	25,50 (4 689)	27,50 (1 846)
512	150	24,50 (2 075)	23,50 (2 876)	24,00 (2 496)	23,00 (2 609)	24,00 (2 831)	24,00 (2 664)	22,00 (4 396)	24,00 (1 559)
640	150	21,00 (1 780)	20,00 (2 449)	20,50 (2 200)	19,50 (2 319)	20,50 (2 537)	20,50 (2 368)	-	20,00 (1 191)
* Limited in reach by longest reach in downstream direction.									

Table 24: Reach requirements for EC ADSL over ISDN downstream with noise model FC

Payload Bitrate (kbit/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	36,50 (2 559)	35,50 (3 319)	36,00 (2 899)	36,00 (3 064)	35,50 (3 166)	36,00 (3 039)	35,50 (4 740)	42,00 (2 284)
768	300	35,00 (2 454)	34,00 (3 179)	34,50 (2 794)	34,00 (2 924)	34,00 (3 061)	34,50 (2 934)	34,00 (4 634)	40,50 (2 179)
1 024	300	32,50 (2 278)	32,00 (2 992)	32,00 (2 618)	32,00 (2 784)	32,00 (2 920)	32,00 (2 758)	31,50 (4 460)	39,00 (2 071)
1 544	300	29,50 (2 068)	28,50 (2 664)	29,00 (2 408)	28,50 (2 538)	28,50 (2 674)	28,50 (2 512)	28,00 (4 216)	35,50 (1 827)
2 048	300	27,00 (1 892)	26,00 (2 430)	26,50 (2 232)	26,00 (2 361)	26,00 (2 499)	26,00 (2 337)	-	33,50 (1 685)
3 072	300	23,50 (1 646)	22,50 (2 103)	22,50 (1 951)	-	22,00 (2 218)	22,50 (2 092)	-	30,00 (1 429)
4 096	300	20,50 (1 436)	19,50 (1 822)	19,50 (1 739)	-	19,00 (2 006)	19,50 (1 881)	-	27,00 (1 247)
5 120	300	17,00 (1 190)	16,50 (1 541)	16,50 (1 532)	-	16,00 (1 799)	-	-	-
6 144	300	14,00 (980)	13,00 (1 214)	-	-	-	-	-	-
* Limited in reach by longest reach in upstream direction.									

Table 25: Reach requirements for EC ADSL over ISDN upstream with noise model FC

Payload Bitrate (kbit/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	150	32,50* (2 751)	30,00* (3 671)	31,00* (3 087)	30,50* (3 243)	30,00* (3 338)	30,50* (3 213)	29,50* (5 027)	35,00* (2 482)
128	150	32,50* (2 751)	30,00* (3 671)	31,00* (3 087)	30,50* (3 243)	30,00* (3 338)	30,50* (3 213)	29,50* (5 027)	34,50 (2 439)
256	150	31,50 (2 666)	30,00* (3 671)	31,00* (3 087)	30,00 (3 201)	30,00* (3 338)	30,50* (3 213)	28,50 (4 944)	31,00 (2 146)
384	150	28,00 (2 371)	26,50 (3 243)	27,50 (2 791)	26,50 (2 907)	27,00 (3 085)	27,00 (2 917)	25,50 (4 689)	27,50 (1 846)
512	150	24,50 (2 075)	23,50 (2 876)	24,00 (2 496)	23,00 (2 609)	24,00 (2 831)	24,00 (2 664)	22,00 (4 396)	24,00 (1 559)
640	150	21,00 (1 780)	20,00 (2 449)	20,50 (2 200)	19,50 (2 319)	20,50 (2 537)	20,50 (2 368)	-	20,00 (1 191)
* Limited in reach by longest reach in downstream direction.									

Table 26: Reach requirements for EC ADSL over ISDN downstream with noise model FD

Payload Bitrate (kbit/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	40,50* (2 840)	43,00* (4 021)	41,50* (3 285)	40,50* (3 380)	41,50* (3 587)	41,50* (3 425)	42,00* (5 196)	44,00* (2 423)
768	300	40,50* (2 840)	43,00* (4 021)	41,50* (3 285)	40,50* (3 380)	41,50* (3 587)	41,50* (3 425)	42,00* (5 196)	44,00* (2 423)
1 024	300	40,50* (2 840)	43,00* (4 021)	41,50* (3 285)	40,50* (3 380)	41,50* (3 587)	41,50* (3 425)	42,00* (5 196)	44,00* (2 423)
1 544	300	40,50* (2 840)	42,00 (3 927)	41,50* (3 285)	40,50* (3 380)	41,50* (3 587)	41,50* (3 425)	41,50 (5 161)	44,00* (2 423)
2 048	300	40,50* (2 840)	40,00 (3 740)	41,00 (3 250)	40,50* (3 380)	40,50 (3 517)	40,50 (3 355)	39,00 (4 985)	44,00* (2 423)
3 072	300	38,00 (2 664)	36,00 (3 366)	37,00 (2 969)	36,50 (3 099)	36,50 (3 236)	37,00 (3 109)	35,00 (4 704)	44,00* (2 423)
4 096	300	33,00 (2 313)	31,50 (2 945)	32,00 (2 618)	31,50 (2 748)	31,00 (2 850)	31,50 (2 723)	29,00 (4 283)	41,00 (2 214)
5 120	300	25,50 (1 787)	23,00 (2 149)	23,50 (2 021)	-	22,00 (2 218)	23,50 (2 162)	-	36,50 (1 900)
6 144	300	16,00 (1 120)	13,50 (1 261)	-	-	-	-	-	29,00 (1 368)
* Limited in reach by longest reach in upstream direction.									

Table 27: Reach requirements for EC ADSL over ISDN upstream with noise model FD

Payload Bitrate (kbit/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	150	33,50 (2 835)	32,50 (3 977)	33,00 (3 256)	32,00 (3 370)	33,00 (3 591)	33,00 (3 424)	31,50 (5 196)	34,00 (2 397)
128	150	32,00 (2 709)	31,00 (3 794)	31,50 (3 129)	30,50 (3 243)	31,00 (3 422)	31,50 (3 297)	29,50 (5 027)	32,00 (2 229)
256	150	29,00 (2 455)	27,50 (3 366)	28,50 (2 876)	27,50 (2 991)	28,00 (3 169)	28,50 (3 044)	26,50 (4 776)	28,50 (1 934)
384	150	25,50 (2 160)	24,50 (2 999)	25,00 (2 580)	24,00 (2 694)	25,00 (2 916)	25,00 (2 748)	23,00 (4 475)	25,50 (1 676)
512	150	22,00 (1 864)	21,00 (2 571)	21,50 (2 285)	20,50 (2 400)	21,50 (2 621)	21,50 (2 453)	-	20,50 (1 242)
640	150	18,50 (1 569)	18,00 (2 204)	18,00 (1 988)	-	18,00 (2 324)	18,00 (2 156)	-	19,50 (1 146)
* Limited in reach by longest reach in downstream direction.									

5.5.2 Performance objectives for EC ADSL over POTS

Tables 28 through 35 provide performance objectives for EC ADSL over POTS with noise models FA through FD. Systems configured as specified in table 19 should meet these performance objectives.

Table 28: Reach requirements for EC ADSL over POTS downstream with noise model FA

Payload Bitrate (kbit/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	41,50 (2 910)	41,00 (3 834)	41,00 (3 250)	41,00 (3 415)	41,00 (3 552)	41,00 (3 390)	41,50 (5 161)	47,00 (2 634)
768	300	39,50 (2 770)	39,00 (3 647)	39,50 (3 145)	39,00 (3 275)	39,00 (3 412)	39,50 (3 285)	39,50 (5 020)	46,00 (2 564)
1 024	300	38,50 (2 700)	37,50 (3 506)	38,00 (3 040)	37,50 (3 170)	37,50 (3 306)	37,50 (3 144)	37,50 (4 880)	45,00 (2 494)
1 544	300	37,00 (2 594)	35,50 (3 319)	36,50 (2 934)	36,00 (3 064)	36,00 (3 201)	36,00 (3 039)	35,50 (4 740)	43,50 (2 388)
2 048	300	35,50 (2 489)	34,50 (3 225)	35,00 (2 829)	34,50 (2 959)	34,50 (3 096)	34,50 (2 934)	34,00 (4 634)	42,00 (2 284)
3 072	300	32,00 (2 243)	31,00 (2 898)	31,50 (2 583)	31,50 (2 748)	31,00 (2 850)	31,50 (2 723)	30,50 (4 387)	38,50 (2 036)
4 096	300	28,50 (1 997)	27,50 (2 570)	27,50 (2 302)	27,50 (2 468)	27,50 (2 604)	27,50 (2 443)	-	35,50 (1 827)
5 120	300	23,50 (1 646)	22,00 (2 056)	22,50 (1 951)	-	21,50 (2 183)	22,00 (2 056)	-	31,50 (1 551)
6 144	300	17,00 (1 190)	15,50 (1 447)	-	-	-	-	-	26,50 (1 186)
* Limited in reach by longest reach in upstream direction.									

Table 29: Reach requirements for EC ADSL over POTS upstream with noise model FA

Payload Bitrate (kbit/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	75	32,50* (3 153)	32,50* (4 721)	32,50* (3 649)	32,50* (3 867)	32,50* (4 024)	32,50* (3 836)	33,00* (6 001)	40,00 (2 828)
128	75	32,50* (3 153)	32,50* (4 721)	32,50* (3 649)	32,50* (3 867)	32,50* (4 024)	32,50* (3 836)	33,00* (6 001)	36,50 (2 489)
256	75	31,50 (3 057)	31,50 (4 576)	31,50 (3 553)	30,50 (3 675)	31,00 (3 880)	31,50 (3 740)	30,00 (5 714)	33,50 (2 205)
384	75	27,00 (2 625)	27,00 (3 926)	27,00 (3 121)	26,00 (3 242)	26,50 (3 448)	26,50 (3 260)	25,50 (5 281)	29,00 (1 782)
512	75	22,50 (2 193)	22,50 (3 275)	22,00 (2 640)	21,50 (2 812)	22,00 (3 016)	22,00 (2 828)	21,50 (4 895)	25,00 (1 344)
640	75	18,00 (1 762)	18,00 (2 625)	18,00 (2 258)	17,00 (2 382)	17,50 (2 585)	18,00 (2 446)	16,50 (4 431)	22,50 (1 132)
* Limited in reach by longest reach in downstream direction.									

Table 30: Reach requirements for EC ADSL over POTS downstream with noise model FB

Payload Bitrate (kbit/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	46,50 (3 261)	46,00 (4 302)	46,50 (3 636)	46,00 (3 766)	46,50 (3 938)	46,50 (3 776)	47,00 (5 547)	52,00 (2 985)
768	300	44,50 (3 121)	44,00 (4 114)	44,00 (3 461)	44,00 (3 626)	44,00 (3 763)	44,00 (3 601)	44,50 (5 372)	50,50 (2 880)
1 024	300	43,00 (3 016)	42,50 (3 974)	42,50 (3 356)	42,50 (3 521)	42,50 (3 657)	42,50 (3 495)	42,50 (5 231)	49,50 (2 810)
1 544	300	41,50 (2 910)	40,00 (3 740)	40,50 (3 215)	40,50 (3 380)	40,50 (3 517)	40,50 (3 355)	40,00 (5 056)	48,00 (2 704)
2 048	300	40,00 (2 805)	38,50 (3 600)	39,00 (3 110)	39,00 (3 275)	39,00 (3 412)	39,00 (3 250)	38,00 (4 915)	46,50 (2 599)
3 072	300	37,00 (2 594)	35,50 (3 319)	36,00 (2 899)	36,00 (3 064)	36,00 (3 201)	36,00 (3 039)	35,50 (4 740)	43,00 (2 353)
4 096	300	34,00 (2 384)	33,00 (3 085)	33,50 (2 724)	33,00 (2 854)	33,00 (2 990)	33,00 (2 828)	32,50 (4 530)	40,50 (2 179)
5 120	300	30,50 (2 138)	29,50 (2 758)	30,00 (2 478)	29,50 (2 608)	29,50 (2 745)	30,00 (2 618)	28,50 (4 249)	37,50 (1 968)
6 144	300	26,50 (1 857)	25,50 (2 383)	26,00 (2 197)	25,50 (2 326)	25,00 (2 429)	25,50 (2 301)	-	34,00 (1 718)
*	Limited in reach by longest reach in upstream direction.								

Table 31: Reach requirements for EC ADSL over POTS upstream with noise model FB

Payload Bitrate (kbit/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	75	38,50* (3 729)	38,00* (5 516)	39,00* (4 272)	39,00* (4 490)	38,50* (4 600)	38,50* (4 412)	39,00* (6 577)	44,50* (3 260)
128	75	38,50* (3 729)	38,00* (5 516)	39,00* (4 272)	39,00* (4 490)	38,50* (4 600)	38,50* (4 412)	39,00* (6 577)	42,00 (3 021)
256	75	37,00 (3 585)	36,50 (5 299)	37,00 (4 080)	36,00 (4 202)	37,00 (4 456)	37,00 (4 268)	35,50 (6 241)	40,00 (2 828)
384	75	32,50 (3 153)	32,50 (4 721)	32,50 (3 649)	32,00 (3 819)	32,50 (4 024)	32,50 (3 836)	31,50 (5 858)	34,50 (2 298)
512	75	28,00 (2 721)	28,00 (4 070)	28,00 (3 217)	27,00 (3 338)	28,00 (3 592)	28,00 (3 404)	27,00 (5 426)	30,00 (1 880)
640	75	23,50 (2 289)	23,50 (3 419)	23,50 (2 785)	22,50 (2 906)	23,50 (3 160)	23,50 (2 972)	22,50 (4 990)	25,50 (1 397)
*	Limited in reach by longest reach in downstream direction.								

Table 32: Reach requirements for EC ADSL over POTS downstream with noise model FC

Payload Bitrate (kbit/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	42,00 (2 945)	45,50 (4 255)	43,50 (3 426)	44,00 (3 626)	43,50 (3 728)	44,00 (3 601)	47,00 (5 547)	47,00 (2 634)
768	300	39,00 (2 735)	40,50 (3 787)	39,00 (3 110)	39,00 (3 275)	39,00 (3 412)	39,00 (3 250)	41,50 (5 161)	44,00 (2 423)
1 024	300	37,00 (2 594)	37,00 (3 459)	37,00 (2 969)	37,00 (3 135)	37,00 (3 271)	37,00 (3 109)	37,50 (4 880)	43,00 (2 353)
1 544	300	34,00 (2 384)	34,00 (3 179)	34,00 (2 759)	34,00 (2 924)	34,00 (3 061)	34,00 (2 899)	34,50 (4 669)	39,50 (2 107)
2 048	300	31,00 (2 173)	31,00 (2 898)	31,00 (2 548)	31,00 (2 713)	31,00 (2 850)	31,00 (2 688)	31,00 (4 424)	36,50 (1 900)
3 072	300	26,50 (1 857)	26,00 (2 430)	26,00 (2 197)	26,00 (2 361)	25,50 (2 464)	26,00 (2 337)	-	32,50 (1 622)
4 096	300	23,00 (1 611)	22,50 (2 103)	22,50 (1 951)	-	22,50 (2 253)	22,50 (2 092)	-	30,00 (1 429)
5 120	300	20,50 (1 436)	19,50 (1 822)	20,00 (1 775)	-	19,50 (2 042)	19,50 (1 881)	-	26,50 (1 186)
6 144	300	17,50 (1 225)	16,50 (1 541)	16,50 (1 532)	-	16,50 (1 834)	-	-	-
* Limited in reach by longest reach in upstream direction.									

Table 33: Reach requirements for EC ADSL over POTS upstream with noise model FC

Payload Bitrate (kbit/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	75	38,50* (3 729)	38,00* (5 516)	39,00* (4 272)	39,00* (4 490)	38,50* (4 600)	38,50* (4 412)	39,00* (6 577)	43,50* (3 164)
128	75	38,50* (3 729)	38,00* (5 516)	39,00* (4 272)	39,00* (4 490)	38,50* (4 600)	38,50* (4 412)	39,00* (6 577)	42,00 (3 021)
256	75	37,00 (3 585)	36,50 (5 299)	37,00 (4 080)	36,00 (4 202)	37,00 (4 456)	37,00 (4 268)	35,50 (6 241)	40,00 (2 828)
384	75	32,50 (3 153)	32,50 (4 721)	32,50 (3 649)	32,00 (3 819)	32,50 (4 024)	32,50 (3 836)	31,50 (5 858)	34,50 (2 298)
512	75	28,00 (2 721)	28,00 (4 070)	28,00 (3 217)	27,00 (3 338)	28,00 (3 592)	28,00 (3 404)	27,00 (5 426)	30,00 (1 880)
640	75	23,50 (2 289)	23,50 (3 419)	23,50 (2 785)	22,50 (2 906)	23,50 (3 160)	23,50 (2 972)	22,50 (4 990)	25,50 (1 397)
* Limited in reach by longest reach in downstream direction.									

Table 34: Reach requirements for EC ADSL over POTS downstream with noise model FD

Payload Bitrate (kbit/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	60,50* (4 244)	67,00* (6 267)	62,00* (4 725)	62,00* (4 890)	63,50* (5 132)	62,50* (4 900)	68,00* (7 022)	57,50* (3 372)
768	300	60,50* (4 244)	64,50 (6 033)	62,00* (4 725)	62,00* (4 890)	63,50* (5 132)	62,50* (4 900)	65,00 (6 811)	57,50* (3 372)
1 024	300	60,50* (4 244)	62,00 (5 799)	62,00* (4 725)	62,00* (4 890)	62,00 (5 027)	62,00 (4 865)	62,00 (6 600)	57,50* (3 372)
1 544	300	58,00 (4 069)	57,50 (5 378)	57,50 (4 409)	57,50 (4 574)	57,50 (4 711)	57,50 (4 549)	57,50 (6 284)	57,50* (3 372)
2 048	300	54,50 (3 823)	53,50 (5 004)	54,00 (4 163)	54,00 (4 328)	54,00 (4 465)	54,00 (4 303)	53,50 (6 004)	57,50* (3 372)
3 072	300	48,50 (3 402)	47,00 (4 395)	48,00 (3 742)	47,50 (3 872)	47,50 (4 008)	47,50 (3 847)	47,00 (5 547)	55,00 (3 196)
4 096	300	43,50 (3 051)	42,00 (3 927)	43,00 (3 391)	42,50 (3 521)	42,50 (3 657)	42,50 (3 495)	41,00 (5 126)	50,50 (2 880)
5 120	300	39,00 (2 735)	37,50 (3 506)	38,00 (3 040)	38,00 (3 205)	37,50 (3 306)	38,00 (3 179)	36,00 (4 775)	47,00 (2 634)
6 144	300	33,50 (2 349)	31,00 (2 898)	32,00 (2 618)	31,00 (2 713)	30,00 (2 780)	31,50 (2 723)	-	42,50 (2 318)
*	Limited in reach by longest reach in upstream direction.								

Table 35: Reach requirements for EC ADSL over POTS upstream with noise model FD

Payload Bitrate (kbit/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	75	44,00 (4 256)	43,00 (6 239)	43,50 (4 704)	43,00 (4 874)	44,00 (5 128)	43,50 (4 892)	43,50 (7 009)	45,50 (3 356)
128	75	40,50 (3 920)	40,00 (5 805)	40,00 (4 368)	39,50 (4 538)	40,50 (4 792)	40,50 (4 604)	39,50 (6 625)	41,50 (2 973)
256	75	36,00 (3 489)	35,50 (5 155)	35,50 (3 936)	35,00 (4 106)	35,50 (4 312)	35,50 (4 124)	34,50 (6 145)	39,00 (2 732)
384	75	31,50 (3 057)	31,50 (4 576)	31,50 (3 553)	30,50 (3 675)	31,00 (3 880)	31,50 (3 740)	30,50 (5 762)	33,00 (2 158)
512	75	26,50 (2 577)	26,50 (3 853)	26,50 (3 073)	26,00 (3 242)	26,50 (3 448)	26,50 (3 260)	25,50 (5 281)	29,00 (1 782)
640	75	22,50 (2 193)	22,50 (3 275)	22,00 (2 640)	21,50 (2 812)	22,00 (3 016)	22,00 (2 828)	21,00 (4 848)	25,00 (1 344)
*	Limited in reach by longest reach in downstream direction.								

5.5.3 Performance objectives for FDD ADSL over ISDN

Tables 36 through 43 provide performance objectives for FDD ADSL over ISDN with noise models FA through FD. Systems configured as specified in table 19 should meet these performance objectives.

Use of the optional tones below 138 kHz, subject to the restrictions imposed by the PSD masks in clause 4.2.2.2, is allowed in the upstream direction to meet the objectives.

Table 36: Reach requirements for FDD ADSL over ISDN downstream with noise model FA

Payload Bitrate (kbit/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	38,00 (2 664)	35,50 (3 319)	36,50 (2 934)	36,00 (3 064)	36,00 (3 201)	36,00 (3 039)	34,50 (4 669)	40,50* (2 179)
768	300	37,50 (2 629)	35,50 (3 319)	36,00 (2 899)	35,50 (3 029)	35,50 (3 166)	35,50 (3 004)	34,00 (4 634)	40,50* (2 179)
1 024	300	37,00 (2 594)	34,50 (3 225)	35,50 (2 864)	35,00 (2 994)	35,00 (3 131)	35,00 (2 969)	33,50 (4 599)	40,50* (2 179)
1 544	300	34,50 (2 419)	32,50 (3 038)	33,00 (2 688)	32,50 (2 819)	32,50 (2 955)	33,00 (2 828)	31,00 (4 424)	40,50* (2 179)
2 048	300	32,00 (2 243)	30,00 (2 804)	30,50 (2 513)	30,00 (2 643)	30,00 (2 780)	30,00 (2 618)	29,00 (4 283)	39,00 (2 071)
3 072	300	27,50 (1 927)	25,50 (2 383)	25,50 (2 162)	25,00 (2 291)	24,50 (2 394)	25,50 (2 301)	-	34,00 (1 718)
4 096	300	19,50 (1 366)	16,50 (1 541)	-	-	-	-	-	29,00 (1 368)
5 120	300	-	-	-	-	-	-	-	-
6 144	300	-	-	-	-	-	-	-	-
* Limited in reach by longest reach in upstream direction.									

Table 37: Reach requirements for FDD ADSL over ISDN upstream with noise model FA

Payload Bitrate (kbit/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	150	31,00 (2 624)	29,50 (3 610)	30,50 (3 044)	29,00 (3 117)	30,50 (3 380)	30,50 (3 213)	28,50* (4 944)	31,00 (2 146)
128	150	29,50 (2 498)	28,50 (3 488)	29,00 (2 918)	27,50 (2 991)	29,00 (3 254)	29,00 (3 086)	27,00 (4 818)	29,00 (1 977)
256	150	25,00 (2 118)	24,50 (2 999)	25,00 (2 580)	23,00 (2 609)	24,50 (2 873)	24,50 (2 706)	22,50 (4 435)	25,00 (1 636)
384	150	19,50 (1 653)	19,00 (2 326)	19,00 (2 073)	-	19,00 (2 409)	19,00 (2 240)	-	20,00 (1 191)
512	150	14,00 (1 189)	13,50 (1 653)	13,00 (1 567)	-	13,00 (1 906)	-	-	-
640	150	3,50 (305)	3,00 (366)	-	-	-	-	-	-
* Limited in reach by longest reach in downstream direction.									

Table 38: Reach requirements for FDD ADSL over ISDN downstream with noise model FB

Payload Bitrate (kbit/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	41,50 (2 910)	39,50 (3 693)	40,50 (3 215)	40,00 (3 345)	40,00 (3 482)	40,00 (3 320)	39,00 (4 985)	46,50* (2 599)
768	300	41,00 (2 875)	38,50 (3 600)	39,50 (3 145)	39,00 (3 275)	39,00 (3 412)	39,50 (3 285)	38,00 (4 915)	46,50* (2 599)
1 024	300	40,00 (2 805)	38,00 (3 553)	38,50 (3 075)	38,00 (3 205)	38,00 (3 341)	38,50 (3 215)	37,00 (4 845)	46,50* (2 599)
1 544	300	38,50 (2 700)	36,50 (3 413)	37,00 (2 969)	36,50 (3 099)	36,50 (3 236)	36,50 (3 074)	35,50 (4 740)	44,00 (2 423)
2 048	300	36,50 (2 559)	34,50 (3 225)	35,00 (2 829)	34,50 (2 959)	34,50 (3 096)	34,50 (2 934)	33,50 (4 599)	42,50 (2 318)
3 072	300	33,00 (2 313)	31,00 (2 898)	31,50 (2 583)	31,00 (2 713)	31,00 (2 850)	31,50 (2 723)	29,50 (4 317)	38,50 (2 036)
4 096	300	28,50 (1 997)	26,50 (2 477)	27,00 (2 267)	26,50 (2 397)	26,00 (2 499)	26,50 (2 372)	-	35,00 (1 789)
5 120	300	22,50 (1 576)	19,50 (1 822)	19,00 (1 704)	-	17,00 (1 868)	18,00 (1 777)	-	30,50 (1 467)
6 144	300	13,00 (909)	10,00 (934)	-	-	-	-	-	-
* Limited in reach by longest reach in upstream direction.									

Table 39: Reach requirements for FDD ADSL over ISDN upstream with noise model FB

Payload Bitrate (kbit/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	150	35,50 (3 004)	32,50* (3 977)	35,00 (3 424)	33,50 (3 497)	34,50* (3 718)	34,50* (3 550)	31,50* (5 196)	36,00 (2 567)
128	150	34,00 (2 878)	32,50* (3 977)	33,50 (3 298)	32,00 (3 370)	33,50 (3 634)	33,50 (3 466)	31,50 (5 196)	33,50 (2 354)
256	150	30,00 (2 540)	29,00 (3 549)	29,50 (2 960)	28,00 (3 032)	29,50 (3 296)	29,50 (3 128)	27,50 (4 861)	29,50 (2 020)
384	150	24,50 (2 075)	23,50 (2 876)	24,00 (2 496)	22,50 (2 566)	24,00 (2 831)	24,00 (2 664)	22,00 (4 396)	24,50 (1 597)
512	150	19,00 (1 611)	18,50 (2 265)	18,50 (2 030)	-	18,50 (2 367)	18,50 (2 198)	-	19,50 (1 146)
640	150	8,00 (684)	7,50 (919)	-	-	-	-	-	-
* Limited in reach by longest reach in downstream direction.									

Table 40: Reach requirements for FDD ADSL over ISDN downstream with noise model FC

Payload Bitrate (kbit/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	33,00 (2 313)	31,50 (2 945)	32,00 (2 618)	31,50 (2 748)	31,50 (2 885)	31,50 (2 723)	30,50 (4 387)	38,50 (2 036)
768	300	31,00 (2 173)	29,50 (2 758)	30,00 (2 478)	29,50 (2 608)	29,50 (2 745)	29,50 (2 582)	28,50 (4 249)	36,00 (1 864)
1 024	300	29,00 (2 033)	27,50 (2 570)	27,50 (2 302)	27,00 (2 432)	27,00 (2 569)	27,50 (2 443)	-	34,50 (1 753)
1 544	300	26,00 (1 822)	24,50 (2 290)	24,50 (2 092)	24,00 (2 223)	24,00 (2 358)	24,50 (2 231)	-	31,50 (1 551)
2 048	300	24,00 (1 681)	22,50 (2 103)	22,50 (1 951)	-	22,00 (2 218)	22,00 (2 056)	-	30,00 (1 429)
3 072	300	20,50 (1 436)	19,50 (1 822)	19,00 (1 704)	-	18,50 (1 971)	19,00 (1 847)	-	26,50 (1 186)
4 096	300	17,00 (1 190)	15,50 (1 447)	-	-	-	-	-	-
5 120	300	13,00 (909)	12,00 (1 120)	-	-	-	-	-	-
6 144	300	-	-	-	-	-	-	-	-
*	Limited in reach by longest reach in upstream direction.								

Table 41: Reach requirements for FDD ADSL over ISDN upstream with noise model FC

Payload Bitrate (kbit/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	150	29,50* (2 498)	26,50* (3 243)	27,50* (2 791)	27,00* (2 949)	27,00* (3 085)	27,00* (2 917)	25,00* (4 645)	32,00* (2 229)
128	150	29,50* (2 498)	26,50* (3 243)	27,50* (2 791)	27,00* (2 949)	27,00* (3 085)	27,00* (2 917)	25,00* (4 645)	32,00* (2 229)
256	150	29,50* (2 498)	26,50* (3 243)	27,50* (2 791)	27,00* (2 949)	27,00* (3 085)	27,00* (2 917)	25,00* (4 645)	29,50 (2 020)
384	150	24,50 (2 075)	23,50 (2 876)	24,00 (2 496)	22,50 (2 566)	24,00 (2 831)	24,00 (2 664)	22,00 (4 396)	24,50 (1 597)
512	150	19,00 (1 611)	18,50 (2 265)	18,50 (2 030)	-	18,50 (2 367)	18,50 (2 198)	-	19,50 (1 146)
640	150	8,00 (684)	7,50 (919)	-	-	-	-	-	-
*	Limited in reach by longest reach in downstream direction.								

Table 42: Reach requirements for FDD ADSL over ISDN downstream with noise model FD

Payload Bitrate (kbit/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	49,00 (3 437)	46,50 (4 348)	47,50 (3 707)	47,50 (3 872)	47,50 (4 008)	47,50 (3 847)	46,00 (5 477)	54,50 (3 161)
768	300	47,00 (3 296)	45,00 (4 208)	46,00 (3 601)	45,50 (3 731)	45,50 (3 868)	45,50 (3 706)	44,00 (5 336)	53,00 (3 056)
1 024	300	45,50 (3 191)	43,00 (4 021)	44,00 (3 461)	43,50 (3 591)	43,50 (3 728)	44,00 (3 601)	42,50 (5 231)	51,50 (2 950)
1 544	300	43,00 (3 016)	40,50 (3 787)	41,50 (3 285)	41,00 (3 415)	41,00 (3 552)	41,00 (3 390)	39,50 (5 020)	49,00 (2 775)
2 048	300	40,50 (2 840)	38,50 (3 600)	39,00 (3 110)	38,50 (3 240)	38,50 (3 376)	39,00 (3 250)	37,50 (4 880)	47,00 (2 634)
3 072	300	36,50 (2 559)	33,50 (3 132)	34,50 (2 794)	33,50 (2 889)	33,50 (3 025)	34,00 (2 899)	31,50 (4 460)	43,00 (2 353)
4 096	300	29,50 (2 068)	26,00 (2 430)	25,50 (2 162)	24,50 (2 257)	23,50 (2 323)	25,00 (2 266)	-	38,00 (2 002)
5 120	300	17,50 (1 225)	13,00 (1 214)	-	-	-	-	-	30,00 (1 429)
6 144	300	-	-	-	-	-	-	-	-
*	Limited in reach by longest reach in upstream direction.								

Table 43: Reach requirements for FDD ADSL over ISDN upstream with noise model FD

Payload Bitrate (kbit/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	150	43,50* (3 680)	38,00* (4 649)	41,50* (3 973)	40,50* (4 088)	40,50* (4 225)	41,00* (4 099)	38,00* (5 745)	46,00* (3 411)
128	150	43,50* (3 680)	38,00* (4 649)	41,50* (3 973)	40,50* (4 088)	40,50* (4 225)	41,00* (4 099)	38,00* (5 745)	46,00* (3 411)
256	150	43,50* (3 680)	38,00* (4 649)	41,50* (3 973)	40,50* (4 088)	40,50* (4 225)	41,00* (4 099)	38,00* (5 745)	46,00* (3 411)
384	150	43,00 (3 637)	38,00* (4 649)	41,50* (3 973)	40,00 (4 046)	40,50* (4 225)	41,00* (4 099)	38,00* (5 745)	42,50 (3 115)
512	150	33,00 (2 793)	31,00 (3 794)	32,50 (3 213)	29,50 (3 159)	32,00 (3 507)	32,00 (3 339)	28,50 (4 944)	32,00 (2 229)
640	150	20,50 (1 738)	15,00 (1 837)	17,50 (1 946)	-	12,00 (1 819)	13,50 (1 775)	-	-
*	Limited in reach by longest reach in downstream direction.								

5.5.4 Performance objectives for FDD ADSL over POTS

Tables 44 through 51 provide performance objectives for FDD ADSL over POTS with noise models FA through FD. Systems configured as specified in table 19 should meet these performance objectives.

Table 44: Reach requirements for FDD ADSL over POTS downstream with noise model FA

Payload Bitrate (kbit/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	38,00 (2 664)	36,50 (3 413)	36,50 (2 934)	36,00 (3 064)	36,00 (3 201)	36,50 (3 074)	35,50 (4 740)	44,00 (2 423)
768	300	37,50 (2 629)	35,50 (3 319)	36,00 (2 899)	35,50 (3 029)	35,50 (3 166)	36,00 (3 039)	34,50 (4 669)	43,50 (2 388)
1 024	300	37,00 (2 594)	35,00 (3 272)	35,50 (2 864)	35,00 (2 994)	35,00 (3 131)	35,50 (3 004)	34,00 (4 634)	43,50 (2 388)
1 544	300	34,50 (2 419)	33,00 (3 085)	33,50 (2 724)	33,00 (2 854)	33,00 (2 990)	33,00 (2 828)	32,00 (4 495)	41,00 (2 214)
2 048	300	32,50 (2 278)	31,50 (2 945)	31,50 (2 583)	31,00 (2 713)	31,00 (2 850)	31,00 (2 688)	30,00 (4 352)	39,00 (2 071)
3 072	300	29,00 (2 033)	27,00 (2 524)	27,50 (2 302)	27,00 (2 432)	26,50 (2 534)	27,00 (2 407)	-	35,50 (1 827)
4 096	300	23,50 (1 646)	21,50 (2 009)	20,50 (1 811)	-	19,00 (2 006)	20,00 (1 915)	-	30,50 (1 467)
5 120	300	16,00 (1 120)	13,50 (1 261)	-	-	-	-	-	-
6 144	300	8,00 (556)	-	-	-	-	-	-	-
* Limited in reach by longest reach in upstream direction.									

Table 45: Reach requirements for FDD ADSL over POTS upstream with noise model FA

Payload Bitrate (kbit/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	75	29,50* (2 865)	25,50* (3 709)	27,50* (3 169)	26,50* (3 290)	26,50* (3 448)	26,50* (3 260)	22,00* (4 943)	38,00* (2 635)
128	75	29,50* (2 865)	25,50* (3 709)	27,50* (3 169)	26,50* (3 290)	26,50* (3 448)	26,50* (3 260)	22,00* (4 943)	36,50 (2 489)
256	75	29,50* (2 865)	25,50* (3 709)	27,50* (3 169)	26,50* (3 290)	26,50* (3 448)	26,50* (3 260)	22,00* (4 943)	32,00 (2 066)
384	75	26,00 (2 529)	25,50* (3 709)	25,50 (2 977)	25,00 (3 145)	25,50 (3 352)	25,50 (3 164)	22,00* (4 943)	27,00 (1 567)
512	75	20,00 (1 953)	20,00 (2 914)	20,00 (2 449)	19,00 (2 576)	20,00 (2 824)	20,00 (2 636)	19,00 (4 664)	23,50 (1 208)
640	75	12,00 (1 184)	12,00 (1 757)	11,50 (1 628)	-	11,50 (2 006)	11,50 (1 812)	-	-
* Limited in reach by longest reach in downstream direction.									

Table 46: Reach requirements for FDD ADSL over POTS downstream with noise model FB

Payload Bitrate (kbit/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	42,00 (2 945)	40,50 (3 787)	41,00 (3 250)	40,50 (3 380)	40,50 (3 517)	41,00 (3 390)	40,00 (5 056)	48,50 (2 740)
768	300	41,50 (2 910)	39,50 (3 693)	40,00 (3 180)	39,50 (3 310)	39,50 (3 447)	40,00 (3 320)	38,50 (4 950)	47,50 (2 669)
1 024	300	40,50 (2 840)	39,00 (3 647)	39,50 (3 145)	39,00 (3 275)	39,00 (3 412)	39,50 (3 285)	38,00 (4 915)	47,00 (2 634)
1 544	300	39,00 (2 735)	37,50 (3 506)	37,50 (3 004)	37,50 (3 170)	37,00 (3 271)	37,50 (3 144)	36,50 (4 810)	45,00 (2 494)
2 048	300	37,00 (2 594)	35,50 (3 319)	36,00 (2 899)	35,50 (3 029)	35,50 (3 166)	36,00 (3 039)	35,00 (4 704)	43,00 (2 353)
3 072	300	34,50 (2 419)	32,50 (3 038)	33,00 (2 688)	32,50 (2 819)	32,50 (2 955)	32,50 (2 793)	31,00 (4 424)	40,00 (2 143)
4 096	300	30,50 (2 138)	29,00 (2 711)	29,00 (2 408)	28,50 (2 538)	28,50 (2 674)	29,00 (2 547)	-	36,50 (1 900)
5 120	300	25,50 (1 787)	24,00 (2 243)	24,00 (2 056)	-	23,00 (2 288)	23,50 (2 162)	-	33,00 (1 653)
6 144	300	19,00 (1 331)	17,00 (1 588)	-	-	-	-	-	28,00 (1 314)
* Limited in reach by longest reach in upstream direction.									

Table 47: Reach requirements for FDD ADSL over POTS upstream with noise model FB

Payload Bitrate (kbit/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	75	32,50* (3 153)	28,00* (4 070)	30,50* (3 457)	30,00* (3 627)	29,50* (3 736)	30,00* (3 596)	25,50* (5 281)	41,00* (2 925)
128	75	32,50* (3 153)	28,00* (4 070)	30,50* (3 457)	30,00* (3 627)	29,50* (3 736)	30,00* (3 596)	25,50* (5 281)	41,00* (2 925)
256	75	32,50* (3 153)	28,00* (4 070)	30,50* (3 457)	30,00* (3 627)	29,50* (3 736)	30,00* (3 596)	25,50* (5 281)	37,50 (2 586)
384	75	31,00 (3 009)	28,00* (4 070)	30,50* (3 457)	30,00* (3 627)	29,50* (3 736)	30,00* (3 596)	25,50* (5 281)	33,00 (2 158)
512	75	25,00 (2 433)	25,00 (3 636)	25,00 (2 929)	24,00 (3 049)	25,00 (3 304)	25,00 (3 116)	24,00 (5 135)	26,50 (1 509)
640	75	17,50 (1 714)	17,50 (2 552)	17,00 (2 163)	16,50 (2 332)	17,50 (2 585)	17,00 (2 351)	16,00 (4 381)	-
* Limited in reach by longest reach in downstream direction.									

Table 48: Reach requirements for FDD ADSL over POTS downstream with noise model FC

Payload Bitrate (kbit/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	35,50 (2 489)	34,50 (3 225)	34,50 (2 794)	34,50 (2 959)	34,00 (3 061)	34,50 (2 934)	34,00 (4 634)	40,00 (2 143)
768	300	33,50 (2 349)	32,50 (3 038)	32,50 (2 653)	32,50 (2 819)	32,00 (2 920)	32,50 (2 793)	31,50 (4 460)	38,50 (2 036)
1 024	300	31,50 (2 208)	30,50 (2 851)	30,50 (2 513)	30,50 (2 678)	30,00 (2 780)	30,50 (2 653)	30,00 (4 352)	36,50 (1 900)
1 544	300	28,50 (1 997)	27,50 (2 570)	27,00 (2 267)	27,00 (2 432)	27,00 (2 569)	27,00 (2 407)	-	33,50 (1 685)
2 048	300	26,00 (1 822)	25,00 (2 336)	24,50 (2 092)	24,50 (2 257)	24,50 (2 394)	24,50 (2 231)	-	31,50 (1 551)
3 072	300	22,50 (1 576)	21,00 (1 962)	21,00 (1 847)	-	20,50 (2 113)	21,00 (1 984)	-	28,00 (1 314)
4 096	300	19,00 (1 331)	18,00 (1 681)	18,00 (1 636)	-	17,50 (1 902)	-	-	-
5 120	300	16,00 (1 120)	15,00 (1 400)	-	-	-	-	-	-
6 144	300	12,50 (873)	11,50 (1 073)	-	-	-	-	-	-
* Limited in reach by longest reach in upstream direction.									

Table 49: Reach requirements for FDD ADSL over POTS upstream with noise model FC

Payload Bitrate (kbit/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	75	27,50* (2 673)	25,00* (3 636)	26,00* (3 025)	25,50* (3 193)	25,00* (3 304)	25,50* (3 164)	22,00* (4 943)	34,50* (2 298)
128	75	27,50* (2 673)	25,00* (3 636)	26,00* (3 025)	25,50* (3 193)	25,00* (3 304)	25,50* (3 164)	22,00* (4 943)	34,50* (2 298)
256	75	27,50* (2 673)	25,00* (3 636)	26,00* (3 025)	25,50* (3 193)	25,00* (3 304)	25,50* (3 164)	22,00* (4 943)	34,50* (2 298)
384	75	27,50* (2 673)	25,00* (3 636)	26,00* (3 025)	25,50* (3 193)	25,00* (3 304)	25,50* (3 164)	22,00* (4 943)	33,00 (2 158)
512	75	25,00 (2 433)	25,00 (3 636)	25,00 (2 929)	24,00 (3 049)	25,00 (3 304)	25,00 (3 116)	22,00* (4 943)	26,50 (1 509)
640	75	17,50 (1 714)	17,50 (2 552)	17,00 (2 163)	16,50 (2 332)	17,50 (2 585)	17,00 (2 351)	16,00 (4 381)	-
* Limited in reach by longest reach in downstream direction.									

Table 50: Reach requirements for FDD ADSL over POTS downstream with noise model FD

Payload Bitrate (kbit/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	66,50 (4 666)	66,00 (6 173)	65,50 (4 971)	65,50 (5 136)	65,50 (5 272)	65,50 (5 110)	65,00 (6 811)	71,00 (4 320)
768	300	63,00 (4 420)	62,50 (5 846)	62,00 (4 725)	62,00 (4 890)	62,00 (5 027)	62,00 (4 865)	61,50 (6 565)	68,00 (4 109)
1 024	300	60,50 (4 244)	59,50 (5 565)	59,50 (4 549)	59,50 (4 714)	59,00 (4 816)	59,50 (4 689)	59,00 (6 390)	65,50 (3 933)
1 544	300	56,00 (3 928)	54,50 (5 097)	54,50 (4 198)	54,50 (4 363)	54,50 (4 500)	54,50 (4 338)	53,50 (6 004)	61,50 (3 653)
2 048	300	52,50 (3 683)	50,50 (4 723)	51,00 (3 952)	50,50 (4 082)	50,50 (4 219)	50,50 (4 057)	49,00 (5 688)	58,00 (3 407)
3 072	300	46,00 (3 226)	43,00 (4 021)	44,00 (3 461)	43,50 (3 591)	43,50 (3 728)	44,00 (3 601)	41,50 (5 161)	52,00 (2 985)
4 096	300	40,50 (2 840)	38,00 (3 553)	38,50 (3 075)	38,00 (3 205)	38,00 (3 341)	38,50 (3 215)	35,00 (4 704)	47,50 (2 669)
5 120	300	34,50 (2 419)	30,50 (2 851)	30,50 (2 513)	29,50 (2 608)	28,00 (2 639)	30,00 (2 618)	-	42,50 (2 318)
6 144	300	20,00 (1 401)	14,00 (1 307)	-	-	-	-	-	36,00 (1 864)
* Limited in reach by longest reach in upstream direction.									

Table 51: Reach requirements for FDD ADSL over POTS upstream with noise model FD

Payload Bitrate (kbit/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	75	53,00* (5 120)	47,00* (6 817)	51,50* (5 472)	50,50* (5 594)	50,00* (5 703)	50,50* (5 563)	46,50* (7 297)	60,00* (4 747)
128	75	53,00* (5 120)	47,00* (6 817)	51,50* (5 472)	50,50* (5 594)	50,00* (5 703)	50,50* (5 563)	46,50* (7 297)	60,00* (4 747)
256	75	53,00* (5 120)	47,00* (6 817)	51,50* (5 472)	50,50* (5 594)	50,00* (5 703)	50,50* (5 563)	46,50* (7 297)	56,00 (4 363)
384	75	48,50 (4 688)	47,00* (6 817)	48,50 (5 184)	48,50 (5 402)	48,50 (5 559)	48,50 (5 372)	46,50* (7 297)	50,00 (3 788)
512	75	43,00 (4 160)	42,50 (6 167)	43,00 (4 656)	42,00 (4 778)	42,50 (4 984)	42,50 (4 796)	41,50 (6 817)	44,50 (3 260)
640	75	31,00 (3 009)	30,50 (4 432)	31,00 (3 505)	30,00 (3 627)	30,50 (3 832)	31,00 (3 692)	28,50 (5 570)	34,50 (2 298)
* Limited in reach by longest reach in downstream direction.									

6 ADSL splitter

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

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

Splitter requirements are defined in the multi-part TS 101 952. ADSL over POTS splitters shall comply with TS 101 952-1-1 [6] and TS 101 952-1-2 [7]. For ADSL over ISDN the splitters shall comply with TS 101 952-1-3 [8].

6.1 Impact on existing baseband services

A splitter filter is required at both ends of the line that 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 11.

The following is advised to maintain minimum guaranteed performance:

- The end-to-end insertion loss from port "Naa" to "Nba" does not exceed the maximum values as specified for the test loops 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 52 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 - D (all in dB) should not exceed the maximum reach in clause 6 of TS 102 080 [1], where D = 4,0 dB for ISDN 4B3T and D = 4,5 dB for ISDN 2B1Q. The reduced reach is to allow for the presence of the splitters and the parallel ADSL transmission.

Table 52: 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 m (see note 1)	NT, LT, or open loop
Laa; Lba	150 m (see note 2)	NT, LT, or open loop
Laa; Lba	50 m (see note 3)	NT, LT, or open loop
NOTE 1: Tests a to g in clause 6.2.4.1 of 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 clause 6.2.4.1 of 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 clause 6.2.4.1 of 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: The given lengths for the cable sections Laa and Lba apply to ISDN transmission between Nat and Nbt at maximum length (insertion loss) according to clause 6.2.4.1 of TS 102 080 [1] minus 4 dB as allowed degradation due to the splitter and parallel ADSL transmission.		

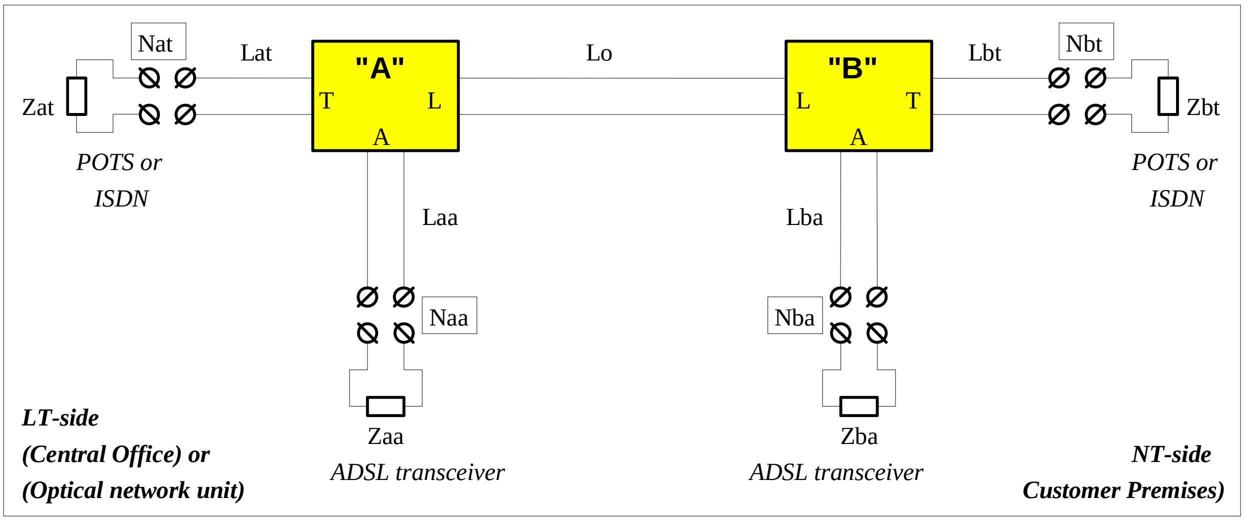


Figure 11: Functional diagram of the ADSL splitter configuration

Annex A (normative): Distributed cable coefficients for the test loop cables

This annex provides the distributed cable coefficients for the cable sections in the test loops in clause 5.2. The characteristics of each cable segment in the test loops shall be consistent with the distributed cable coefficients generated according to

$$Z_s = R_s + j\omega L_s = \left(\frac{1}{\sqrt[4]{R_{oc}^4 + a_c f^2}} + \frac{1}{\sqrt[4]{R_{os}^4 + a_s f^2}} \right)^{-1} + j\omega \left(\frac{L_0 + L_\infty \left(f / f_m \right)^{Nb}}{1 + \left(f / f_m \right)^{Nb}} \right)$$

and

$$Y_p = G_p + j\omega C_p = g_0 f^{Nge} + j\omega \left(C_\infty + \frac{C_0}{f^{Nce}} \right),$$

where the parameters for each cable type are taken from table A.1. The resulting distributed coefficients R_s, L_s and C_p are consistent with the tabulated values in tables A.2 through A.6.

Table A.1: Parameter set for generating distributed cable coefficients

	PE032	PE04	PE05	PE063	PE09
R_{oc} (Ω/km)	409	280	179	113	55
a_c	0,3822	0,0969	0,0561	0,0256	0,0094
R_{os} (Ω/km)	∞	∞	∞	∞	∞
a_s	0	0	0	0	0
L_0 (µH/km)	607,64	587,13	673,57	699,26	750,79
L_∞ (µH/km)	500	427,12	544,25	477,42	520,45
f_m (kHz)	608,77	739,05	580,92	265,7	124,04
N_b	5,2464	1,3952	1,3013	1,0978	0,9605
g_0 (S/km)	0	0	0	0	0
N_{ge}	0	0	0	0	0
C_0 (nF/km)	0	0	0	0	0
C_∞ (nF/km)	40	50	50	45	40
N_{ce}	0	0	0	0	0

Table A.2: R_s L_s C_p values for 0,32 mm PE cable (ADSL.PE032)

Frequency (kHz)	R_s (Ω/km)	L_s (µH/km)	C_p (nF/km)
0,00	409,000	607,640	40,00
2,50	409,009	607,640	40,00
10,00	409,140	607,640	40,00
20,00	409,557	607,640	40,00
30,00	410,251	607,640	40,00
40,00	411,216	607,640	40,00
50,00	412,448	607,640	40,00
100,00	422,302	607,632	40,00
150,00	437,339	607,571	40,00
200,00	456,088	607,328	40,00
250,00	477,232	606,640	40,00
300,00	499,762	605,075	40,00
350,00	522,973	602,047	40,00
400,00	546,402	596,935	40,00
450,00	569,755	589,338	40,00
500,00	592,851	579,377	40,00
550,00	615,584	567,823	40,00
600,00	637,894	555,868	40,00
650,00	659,752	544,658	40,00
700,00	681,148	534,942	40,00
750,00	702,083	526,992	40,00
800,00	722,567	520,732	40,00
850,00	742,612	515,919	40,00
900,00	762,236	512,265	40,00
950,00	781,454	509,503	40,00
1 000,00	800,284	507,415	40,00
1 050,00	818,744	505,831	40,00
1 100,00	836,850	504,623	40,00

Table A.3: R_s L_s C_p values for 0,4 mm PE cable (ADSL.PE04)

Frequency (kHz)	R_s (Ω/km)	L_s (μH/km)	C_p (nF/km)
0,00	280,000	587,130	50,00
2,50	280,007	587,073	50,00
10,00	280,110	586,736	50,00
20,00	280,440	586,097	50,00
30,00	280,988	585,320	50,00
40,00	281,749	584,441	50,00
50,00	282,719	583,481	50,00
100,00	290,437	577,877	50,00
150,00	302,078	571,524	50,00
200,00	316,406	564,888	50,00
250,00	332,365	558,232	50,00
300,00	349,188	551,714	50,00
350,00	366,370	545,430	50,00
400,00	383,590	539,436	50,00
450,00	400,658	533,759	50,00
500,00	417,462	528,409	50,00
550,00	433,941	523,385	50,00
600,00	450,067	518,677	50,00
650,00	465,827	514,272	50,00
700,00	481,224	510,153	50,00
750,00	496,264	506,304	50,00
800,00	510,959	502,707	50,00
850,00	525,324	499,343	50,00
900,00	539,372	496,197	50,00
950,00	553,118	493,253	50,00
1 000,00	566,576	490,494	50,00
1 050,00	579,761	487,908	50,00
1 100,00	592,686	485,481	50,00

Table A.4: R_s L_s C_p values for 0,5 mm PE cable (ADSL.PE05)

Frequency (kHz)	R_s (Ω/km)	L_s (μH/km)	C_p (nF/km)
0,00	179,000	673,570	50,00
2,50	179,015	673,462	50,00
10,00	179,244	672,919	50,00
20,00	179,970	671,976	50,00
30,00	181,161	670,892	50,00
40,00	182,790	669,712	50,00
50,00	184,823	668,464	50,00
100,00	199,612	661,674	50,00
150,00	218,729	654,618	50,00
200,00	239,143	647,732	50,00
250,00	259,474	641,206	50,00
300,00	279,189	635,116	50,00
350,00	298,120	629,486	50,00
400,00	316,249	624,307	50,00
450,00	333,611	619,556	50,00
500,00	350,264	615,201	50,00
550,00	366,268	611,210	50,00
600,00	381,680	607,551	50,00
650,00	396,553	604,191	50,00
700,00	410,933	601,103	50,00
750,00	424,861	598,260	50,00
800,00	438,376	595,639	50,00
850,00	451,509	593,216	50,00
900,00	464,288	590,975	50,00
950,00	476,740	588,896	50,00
1 000,00	488,888	586,965	50,00
1 050,00	500,752	585,169	50,00
1 100,00	512,350	583,495	50,00

Table A.5: R_s L_s C_p values for 0,63 mm PE cable (ADSL.PE063)

Frequency (kHz)	R_s (Ω/km)	L_s (µH/km)	C_p (nF/km)
0,00	113,000	699,260	45,00
2,50	113,028	697,945	45,00
10,00	113,441	693,363	45,00
20,00	114,734	687,010	45,00
30,00	116,796	680,716	45,00
40,00	119,512	674,594	45,00
50,00	122,752	668,691	45,00
100,00	143,076	642,718	45,00
150,00	164,880	622,050	45,00
200,00	185,617	605,495	45,00
250,00	204,911	592,047	45,00
300,00	222,866	580,959	45,00
350,00	239,661	571,689	45,00
400,00	255,463	563,843	45,00
450,00	270,414	557,127	45,00
500,00	284,627	551,321	45,00
550,00	298,197	546,258	45,00
600,00	311,200	541,807	45,00
650,00	323,699	537,866	45,00
700,00	335,746	534,355	45,00
750,00	347,387	531,209	45,00
800,00	358,658	528,375	45,00
850,00	369,592	525,810	45,00
900,00	380,217	523,478	45,00
950,00	390,558	521,349	45,00
1 000,00	400,635	519,399	45,00
1 050,00	410,469	517,606	45,00
1 100,00	420,075	515,953	45,00

Table A.6: R_s L_s C_p values for 0,9 mm PE cable (ADSL.PE09)

Frequency (kHz)	R_s (Ω/km)	L_s (µH/km)	C_p (nF/km)
0,00	55,000	750,790	40,00
2,50	55,088	745,498	40,00
10,00	56,361	731,955	40,00
20,00	59,943	716,770	40,00
30,00	64,780	703,870	40,00
40,00	70,131	692,703	40,00
50,00	75,591	682,910	40,00
100,00	100,779	647,493	40,00
150,00	121,878	625,138	40,00
200,00	140,090	609,652	40,00
250,00	156,290	598,256	40,00
300,00	171,006	589,504	40,00
350,00	184,576	582,563	40,00
400,00	197,229	576,919	40,00
450,00	209,126	572,237	40,00
500,00	220,388	568,288	40,00
550,00	231,106	564,911	40,00
600,00	241,352	561,989	40,00
650,00	251,182	559,435	40,00
700,00	260,643	557,184	40,00
750,00	269,774	555,184	40,00
800,00	278,607	553,395	40,00
850,00	287,169	551,785	40,00
900,00	295,484	550,328	40,00
950,00	303,571	549,003	40,00
1 000,00	311,449	547,794	40,00
1 050,00	319,134	546,684	40,00
1 100,00	326,637	545,663	40,00

Annex B (informative): Transmission of cable sections

B.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 B.1 and B.2):

$$\text{Transmission Function} = \frac{U_2}{U_1}$$

$$\text{Insertion Loss} = \frac{U_1}{U_2}$$

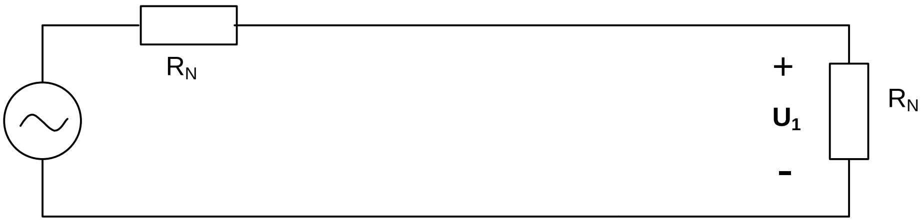


Figure B.1: Voltage across the load

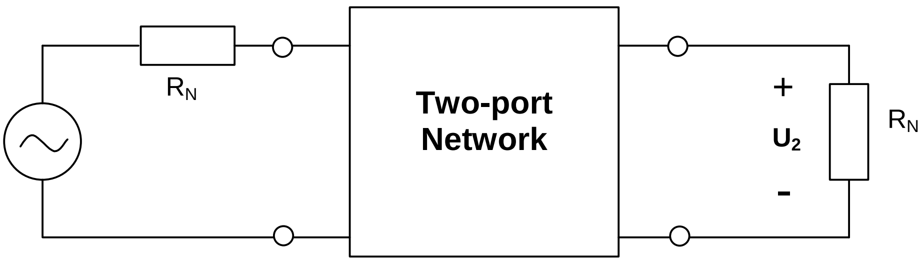


Figure B.2: Voltage across the load with a two-port network inserted

These quantities are directly related to the scattering parameters associated with the two-port network as defined in clause B.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 $\log_{10}(|s_{21}|)$

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

The test loops are defined by one or a cascade of cable sections. The characteristics of each section are specified by primary cable parameters $\{Z_s, Y_p\}$ per unit length (L_0), as described in annex A. This clause provides the equations to evaluate the relevant characteristics of cable sections (s-parameters) from the primary parameters and defines how to handle cascades of cable sections.

Insertion loss and return loss of a cable section, normalized to a chosen reference impedance $\mathbf{R_N}$, 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 $\mathbf{R_N}$ as follows:

NOTE: ETSI has chosen the value of 135 Ω for R_N to describe cables, but the formulas in this annex do not lose their validity if other values are chosen for other applications.

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

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

Insertion Loss: $1/s_{21 \text{ normalized to } R_N}$.

Return Loss: $1/s_{11 \text{ normalized to } R_N}$.

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:

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

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

This annex describes the ADSL over ISDN configuration of modems based on ANSI T1.413 [5]. 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:

- mirrored complex-conjugate of tones 33 to 63 if the transmitter uses only 32 tones (tone #32 = 0);
- zero if the transmitter uses 64 tones and the receiver uses 32 tones (tone #32 = 0);
- 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.

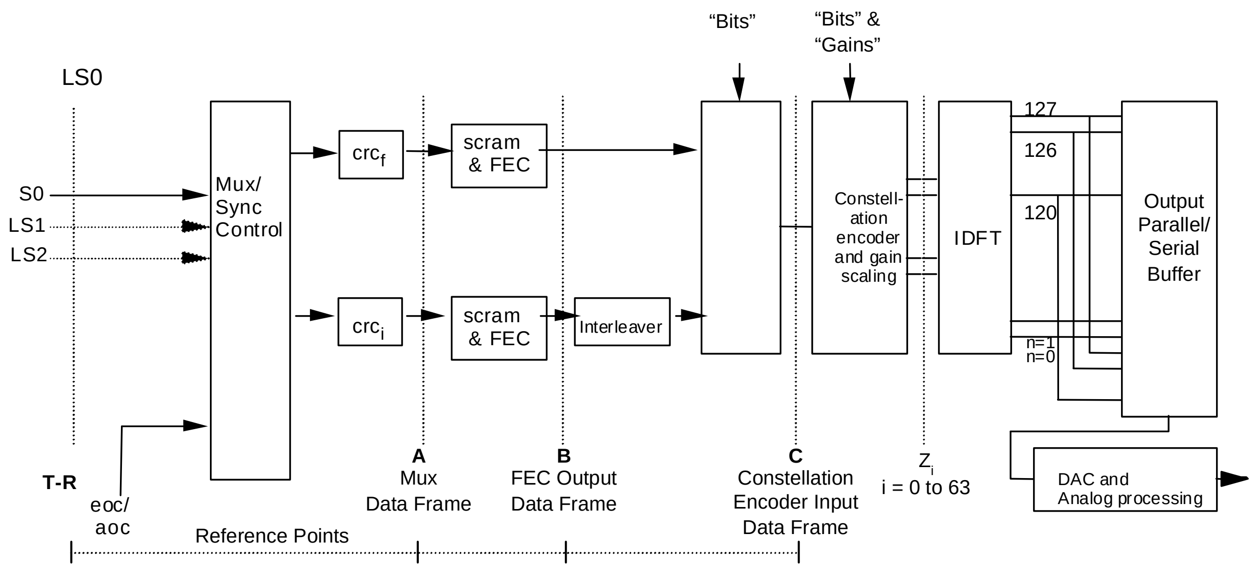


Figure C.1: ATU-R transmitter reference model for STM transport

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

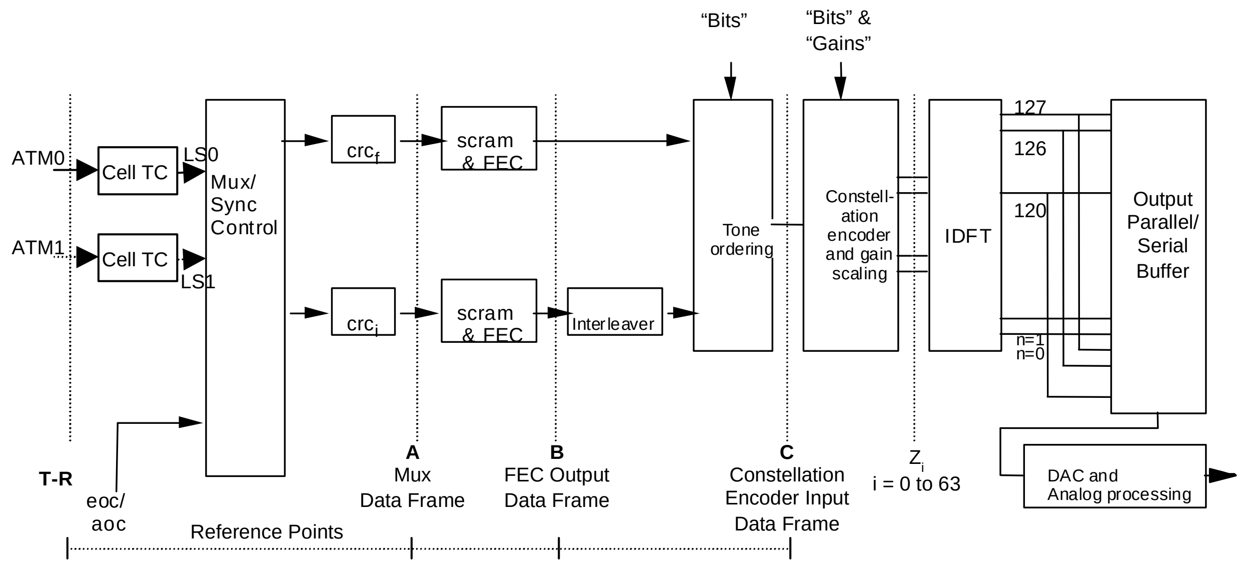


Figure C.2: ATU-R transmitter reference model for ATM transport

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.

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 uses 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-REVERB1 in 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 continues 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) 001.0 1000 0000 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 (0 000 and 0 0000 000 0 000, 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 (000.1 100000 00 to 001.0 1010 1011).

A total of 126 bits and gains information are 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.

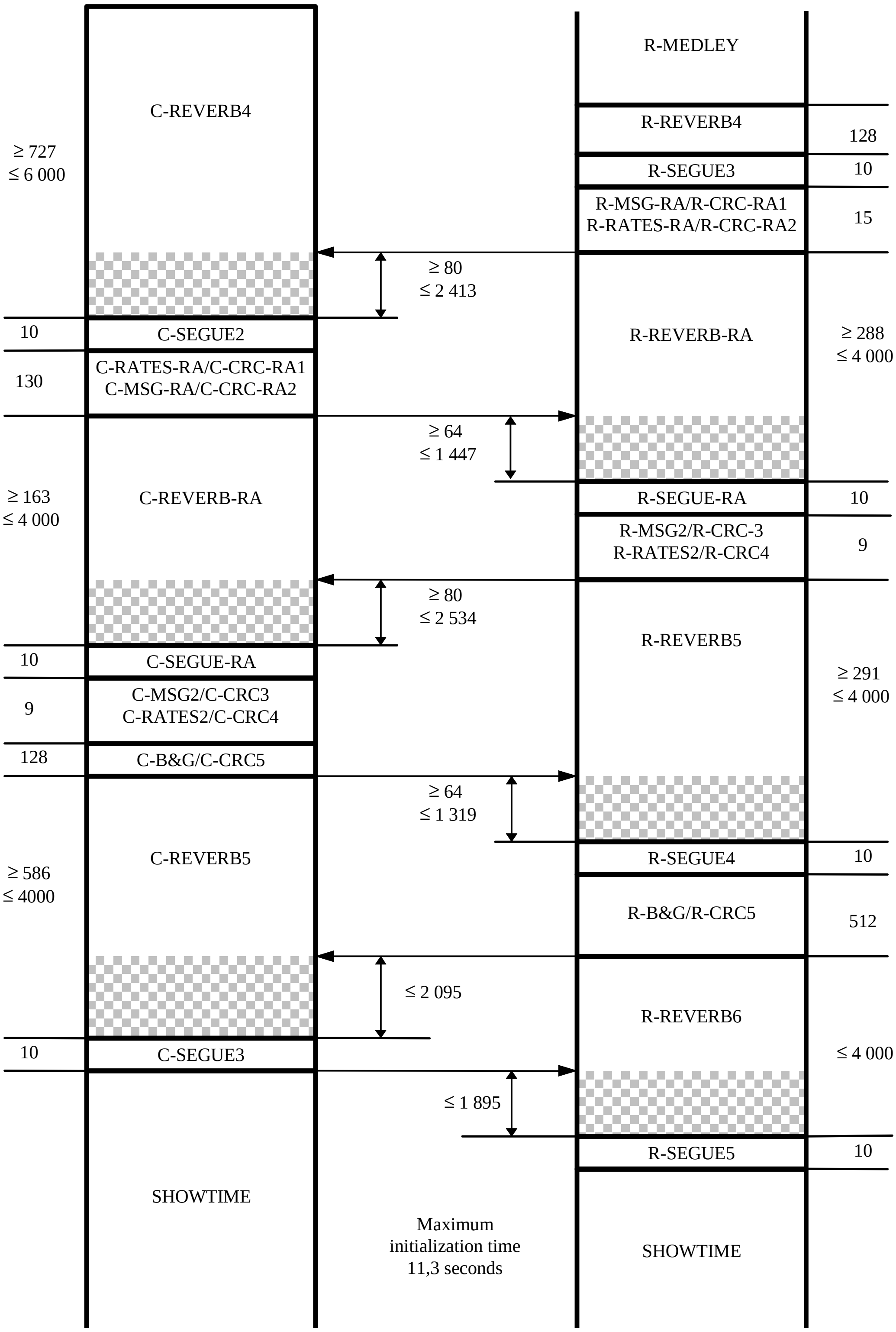


Figure C.3: Timing diagram of the initialization sequence

Annex D (informative): PSD masks for ADSL over POTS as specified in ITU-T Recommendation 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.

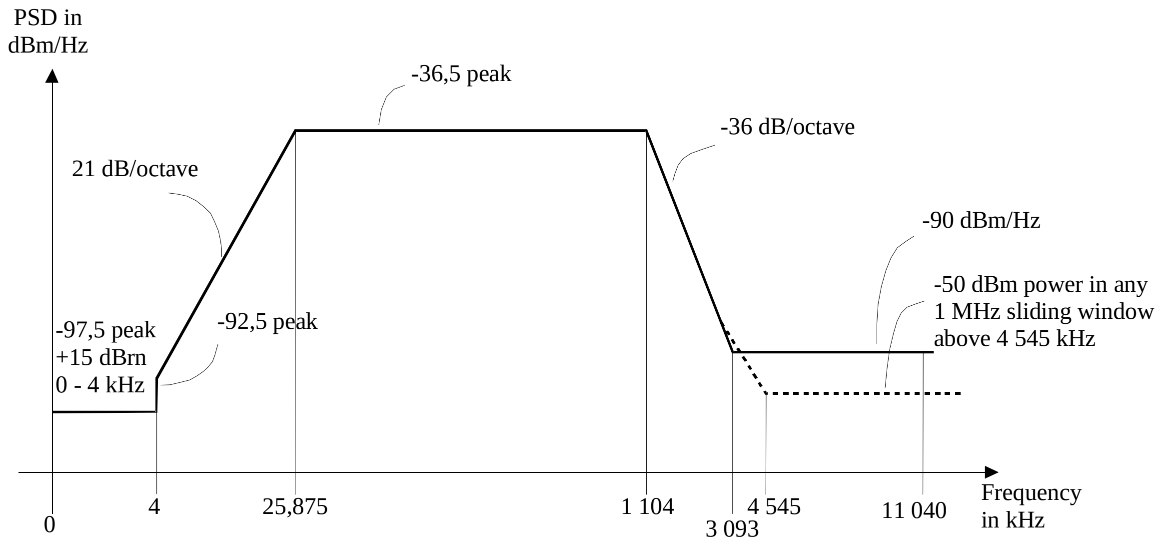


Figure D.1: ATU-C transmitted PSD mask

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 -f -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 -f -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 ITU-T Recommendation G.992.1 [2], figure 1.1); the signals delivered to the PSTN are specified in annex E of ITU-T Recommendation G.992.1 [2].

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.

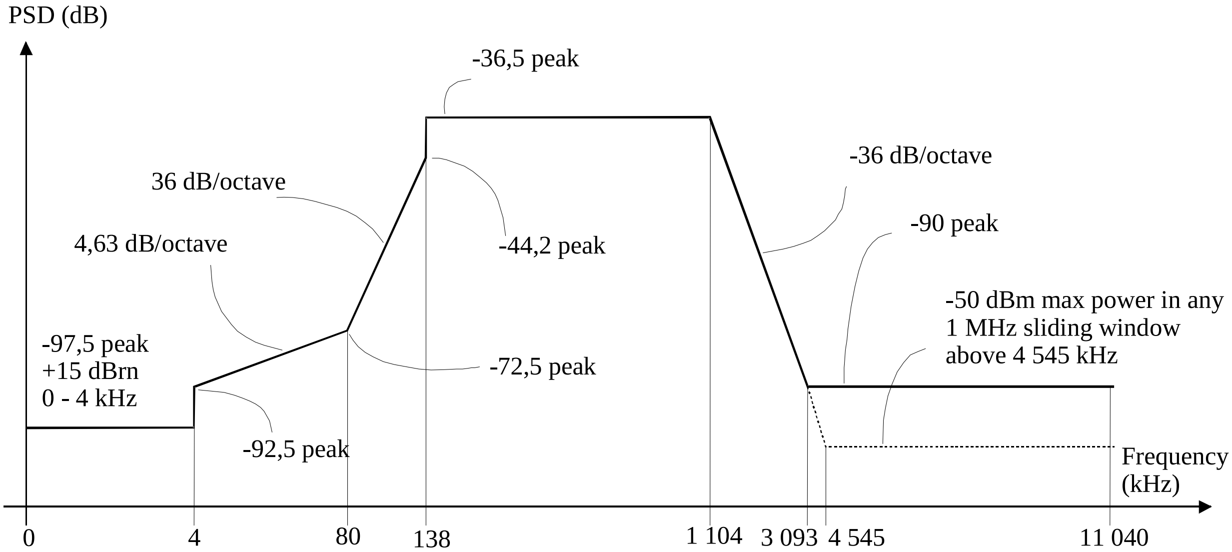


Figure D.2: ATU-C transmitter PSD mask for reduced NEXT

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 -f -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 -f -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 ITU-T Recommendation G.992.1 [2], figure 1.1); the signals delivered to the PSTN are specified in annex E of ITU-T Recommendation G.992.1 [2].

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 kHz to 138 kHz shown. The low-frequency stop-band is defined as the voiceband.

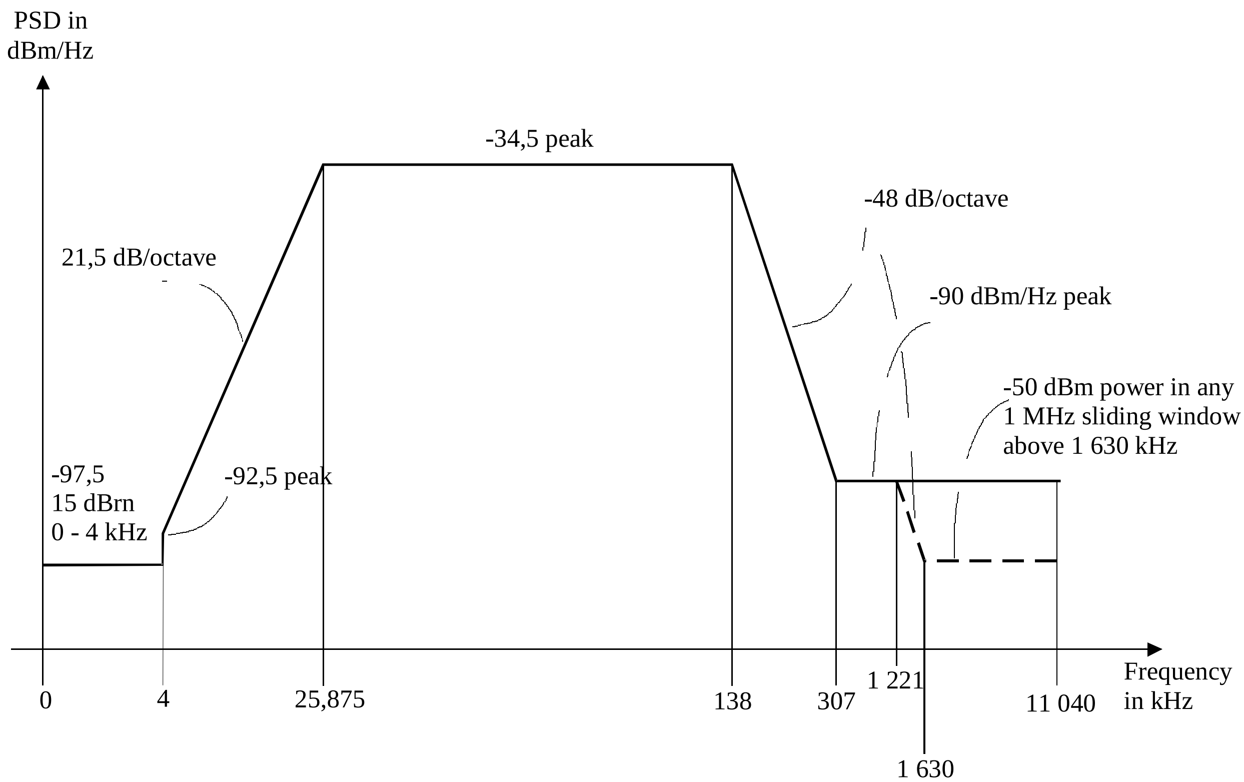


Figure D.3: ATU-R transmitter PSD mask

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 -f -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 -f -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 ITU-T Recommendation G.992.1 [2], figure 1.1); the signals delivered to the PSTN are specified in annex E of ITU-T Recommendation G.992.1 [2].

Annex E (informative): Characteristics of all digital loop signals

The PSD masks in this annex are intended for use with ITU Recommendation G.dmt.bis currently under development in the ITU. If for some reason the completion of G.dmt.bis is delayed indefinitely, these PSD masks can be used with ITU-T Recommendation G.992.1 [2]. The description in this annex is signal description only and not a system description. European specific requirements such as performance requirements are for further study. Future ITU refinements of ADL signal descriptions will supercede the signal descriptions in this annex.

When ADL systems are deployed in the same cable with other types of xDSL systems, there may be spectral compatibility issues. These issues are currently being studied within the ETSI TM6 Spectrum Management projects. As a result general deployment restrictions for xDSL systems may be imposed (e.g. by the regional regulatory authority), for example, for those using the PSD masks defined in this annex.

E.1 All digital mode ADSL derived from ADSL over POTS

E.1.1 ATU-C downstream transmit spectral mask for overlapped spectrum operation

The passband is defined as the band from 3 kHz to 1 104 kHz and is the widest possible band used (i.e. implemented with overlapped spectrum). Limits defined within the passband apply also to any narrower bands used.

Figure E.1 defines the spectral mask for the transmit signal. The low-frequency stop-band is defined as frequencies below 3 kHz, the high-frequency stop-band is defined as frequencies greater than 1 104 kHz. Limitations on aggregate transmit power are specified in clause E.3.

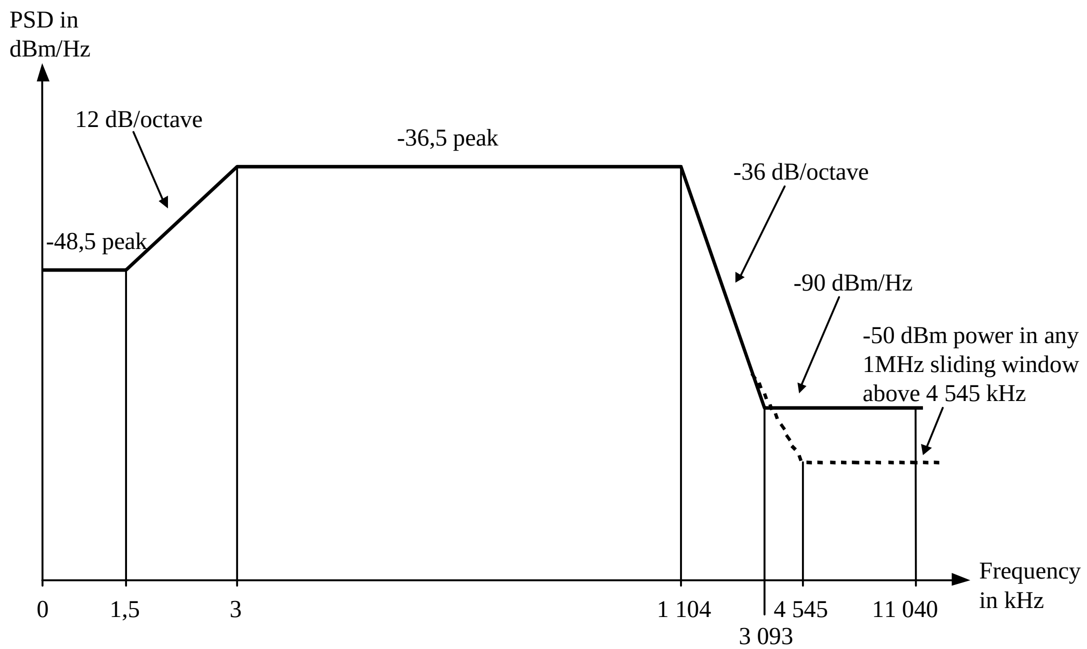


Figure E.1: All digital mode downstream PSD mask for overlapped operation

Table E.1: Definition of all digital mode downstream

Frequency band f (kHz)	Equation for line (dBm/Hz)
$0 < f < 1{,}5$	-48,5
$1{,}5 < f < 3$	$-36{,}5 + 12 \times \log_2(f/3)$
$3 < f < 1\,104$	-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. NOTE 2: The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. NOTE 3: Above 3 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth. Below 3 kHz, the peak PSD shall be measured with a 100 Hz 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: All PSD and power measurements shall be made at the U-C interface (see ITU-T Recommendation G.992.1 [2], figure 1.1).	

NOTE: When deployed in the same cable as ADSL over POTS (ITU-T Recommendation G.992.1 [2], annex A and ITU-T Recommendation G.992.2 [9], annexes A and B) there may be a spectral compatibility issue between the two systems due to the overlap of the All Digital Loop downstream channel with the ADSL over POTS upstream channel at frequencies below 138 kHz. Detailed study of spectrum compatibility is referred to regional bodies. Deployment restrictions for systems using the downstream PSD masks defined in this annex may be imposed (e.g. by the regional regulatory authority).

E.1.1.1 Passband PSD and response

Across the whole passband, the transmit PSD level shall not exceed the maximum passband transmit PSD level corrected by power cut back as appropriate.

The maximum passband transmit PSD level allows for a 1 dB of non-ideal transmit filter effects (e.g. passband ripple and transition band rolloff).

E.1.2 ATU-C downstream transmit spectral mask for non-overlapped spectrum operation

The ATU-C transmit spectral mask shall be identical to the ATU-C transmit spectral mask for non-overlapped spectrum operation over POTS, as defined in clause 4.1.2.

E.1.3 ATU-R upstream transmit spectral mask

The passband is defined as the band from 3 kHz to 138 kHz and is the widest possible band used. Limits defined within the passband apply also to any narrower bands used.

Figure E.2 defines the spectral mask for the transmit signal. The low-frequency stop-band is defined as frequencies below 3 kHz, the high-frequency stop-band is defined as frequencies greater than 138 kHz. Limitations on aggregate transmit power are specified in clause E.3.

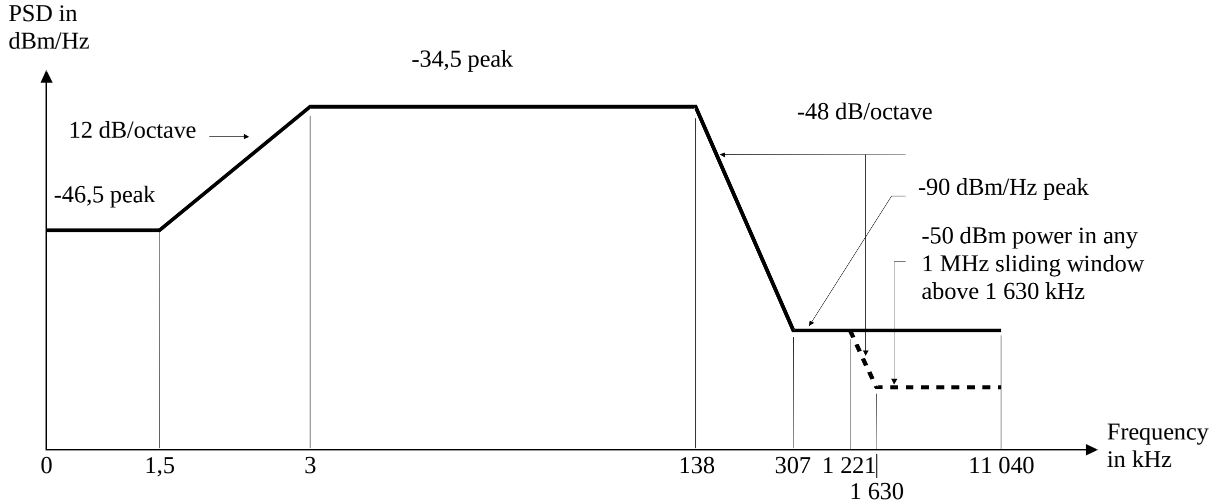


Figure E.2: All digital mode upstream PSD mask

Table E.2: Definition of all digital mode upstream

Frequency band *f* (kHz)	**Equation for line (dBm/Hz)**
$0 < f < 1,5$	-46,5
$1,5 < f < 3$	$-34,5 + 12 \times \log_2(f/3)$
$3 < f < 138$	-34,5
$138 < f < 307$	$-34,5 - 48 \times \log_2(f/138)$
$307 < f < 1\ 221$	-90 peak, with max power in the [f, $f + 100$ kHz] window of -42,5 dBm
$1\ 221 < f < 1\ 630$	-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. NOTE 2: The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. NOTE 3: Above 3 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth. Below 3 kHz, the peak PSD shall be measured with a 100 Hz 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: All PSD and power measurements shall be made at the U-R interface (see ITU-T Recommendation G.992.1 [2], figure 1.1).	

E.1.3.1 Passband PSD and response

Across the whole passband, the transmit PSD level shall not exceed the maximum passband transmit PSD level corrected by power cut back as appropriate.

The maximum transmit PSD allows for a 1 dB of non-ideal transmit filter effects (e.g. passband ripple and transition band rolloff).

E.2 All digital mode ADSL derived from ADSL over ISDN

E.2.1 ATU-C downstream transmit spectral mask for overlapped spectrum operation

The ATU-C transmit spectral mask shall be identical to the ATU-C transmit spectral mask defined in clause E.1.1.

E.2.2 ATU-C downstream transmit spectral mask for non-overlapped spectrum operation

The ATU-C transmit spectral mask shall be identical to the ATU-C transmit spectral mask for non-overlapped spectrum operation over ISDN, as defined in clause 4.2.2.1.

E.2.3 ATU-R upstream transmit spectral mask

The ATU-R transmit PSD shall comply to one of the allowed family of spectral masks ADLU-32, ADLU-36 to ADLU-64 as defined in table E.3. Each of the spectral masks shall be as defined in figure E.3 and table E.3. Limitations on aggregate transmit power are specified in clause E.3.

The passband is defined as the band from 3 kHz to an upper bound frequency f1, defined in table E.3. It is the widest possible band used. Limits defined within the passband apply also to any narrower bands used.

Figure E.3 defines the family of ATU-R spectral masks for the transmit signal. The low-frequency stop-band is defined as frequencies below 3 kHz; the high-frequency stop-band is defined as frequencies greater than the passband upper bound frequency f1 defined in table E.3. The frequencies f1 and f2 shall be as defined in table E.3a.

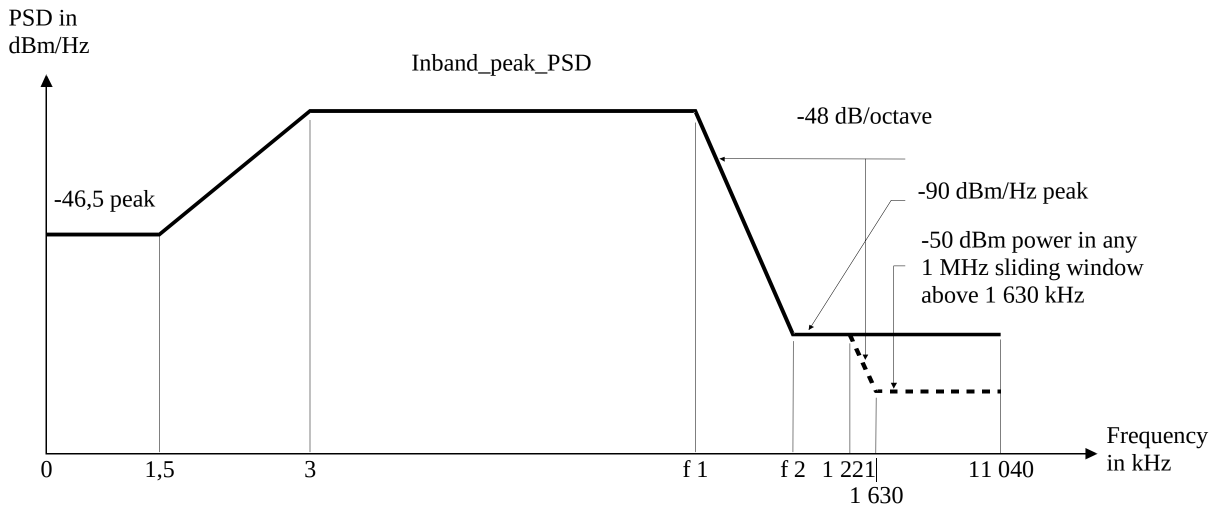


Figure E.3: The family of ATU-R upstream transmit PSD masks

Table E.3: Definition of the family of ATU-R upstream

Frequency band *f* (kHz)	Equation for Line (dBm/Hz)
0 < *f* < 1,5	-46,5
1,5 < *f* < 3	-46,5 + (Inband_peak_PSD+46,5) x $\log_2$(*f*/1,5 kHz)
3 < *f* < *f1*	Inband_peak_PSD
f1 < *f* < *f2*	Inband_peak_PSD - 48 $\log_2$(*f* / *f1*)
f2 < *f* < 1 221	-90
1 221 < *f* < 1 630	-90 peak, with max power in the [*f*, *f* + 1 MHz] window of (-30 - 48 $\log_2$(*f*/1 221 kHz)) dBm
1 630 < *f* < 11 040	-90 peak, with max power in the [*f*, *f* + 1 MHz] window of -50 dBm
NOTE 1: All PSDs are measured over a 100 Ω termination. NOTE 2: The breakpoint frequencies and the PSD values are exact, the indicated slopes are approximate. NOTE 3: Above 3 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth. Below 3 kHz, the peak PSD shall be measured with a 100 Hz 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: All PSD and power measurements shall be made at the U-R interface (see ITU-T Recommendation G.992.1 [2], see figure 1.1).	

Table E.3a: Inband peak PSD and frequency f1, f2

Upstream mask-number	Designator	NOMPSD and MAXPSD (dBm/Hz)	MAXATP (dBm)	Inband Peak PSD (dBm/Hz)	Frequency *f1* (kHz)	Frequency *f2* (kHz)
1	ADLU-32	-38,0	13,4	-34,5	138,00	307
2	ADLU-36	-38,5	13,4	-35,0	155,25	343
3	ADLU-40	-39,0	13,4	-35,5	172,50	379
4	ADLU-44	-39,4	13,4	-35,9	189,75	415
5	ADLU-48	-39,8	13,4	-36,3	207,00	450
6	ADLU-52	-40,1	13,4	-36,6	224,25	485
7	ADLU-56	-40,4	13,4	-36,9	241,50	520
8	ADLU-60	-40,7	13,4	-37,2	258,75	554
9	ADLU-64	-41,0	13,4	-37,5	276,00	589
NOTE 1: MAXPSD is the maximum nominal transmit PSD (MAXPSD) level during initialization and showtime. The parameter can be different for the ATU-C (MAXPSDds) and the ATU-R (MAXPSDus). NOTE 2: NOMPSD is the nominal transmit PSD level (NOMPSD). It is defined as the transmit PSD level in the passband at the start of initialization, relative to which spectral shaping and power cut back are applied. The parameter can be different for the ATU-C (NOMPSDds) and the ATU-R (NOMPSDus). Its value depends on near-end transmitter capabilities and shall be no higher than the MAXPSD value. NOTE 3: MAXATP is the maximum nominal aggregate transmit power (MAXATP) level during initialization and showtime. The parameter can be different for the ATU-C (MAXATPds) and the ATU-R (MAXATPus).						

The family of ATU-R transmit spectral templates corresponding to the ATU-R transmit spectral masks are shown in figure E.4. For comparison, the ATU-R transmit spectral template for ADSL over ISDN (see clause 4.2.1.2) is also shown.

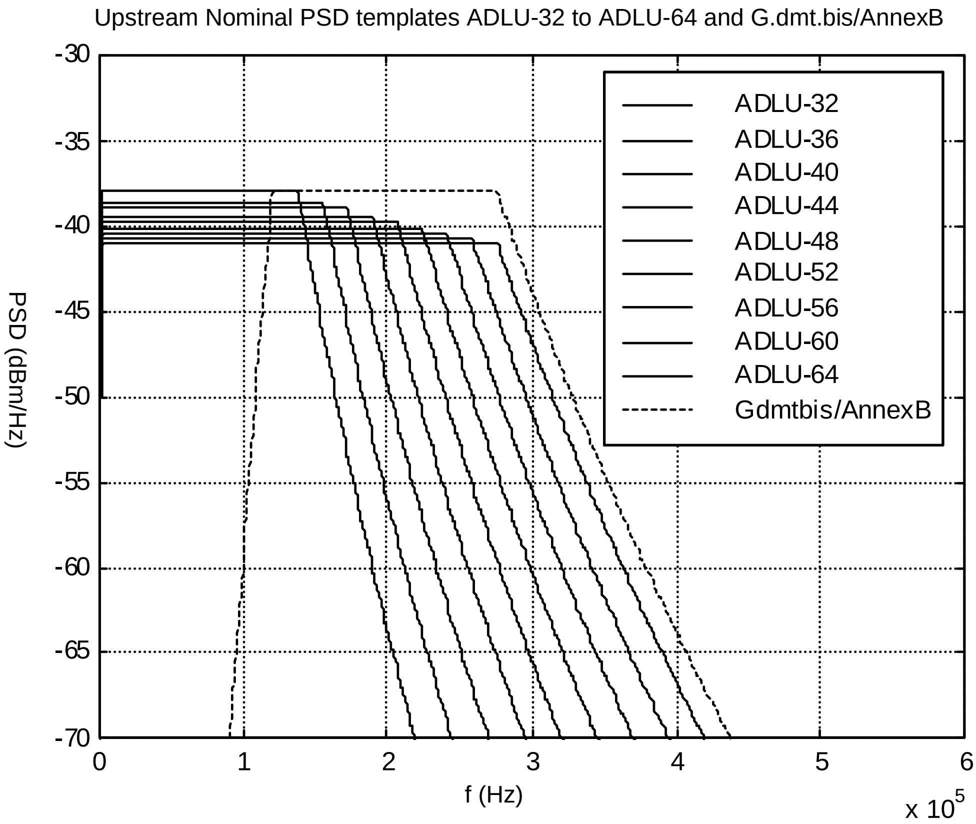


Figure E.4: The family of ATU-R transmit spectrum templates

NOTE: When deployed in the same cable as ADSL over POTS (ITU-T Recommendation G.992.1 [2], annex A and ITU-T Recommendation G.992.2 [9], annexes A and B) there may be a spectral compatibility issue between the two systems due to the overlap of the All Digital Loop upstream channel with the ADSL over POTS downstream channel at frequencies above 138 kHz. Detailed study of spectrum compatibility is referred to regional bodies. Deployment restrictions for systems using the upstream PSD masks defined in this annex may be imposed (e.g. by the regional regulatory authority).

E.2.3.1 Passband PSD and response

Across the whole passband, the transmit PSD level shall not exceed the maximum passband transmit PSD level corrected by power cut back as appropriate.

The maximum transmit PSD allows for a 1 dB of non-ideal transmit filter effects (e.g. passband ripple and transition band rolloff).

E.3 Aggregate transmit power

There are several different PSD masks defined for the ADL transmit signals, depending on the type of signal sent (see clauses E.1.1.1, E.1.2.1 and E.2.3.1). In all cases,

- the aggregate transmit power shall not exceed the transmit power given in table E.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);
- the aggregate transmit power across the whole passband shall not exceed the maximum aggregate transmit power (minus the power cut-back) by more than 0,5 dB, in order to accommodate implementational tolerances;
- the aggregate transmit power over the 0 MHz to 11,040 MHz band, shall not exceed the maximum aggregate transmit power (minus the power cut-back) by more than 0,8 dB for upstream signals and 0,9 dB for downstream signals, in order to account for residual transmit power in the stop bands and implementational tolerances.

The power emitted by the ATU-R is limited by the requirements in this clause. Notwithstanding these requirements, it is assumed that the ADSL will comply with applicable national requirements on emission of electromagnetic energy.

Table E.4: Maximum aggregate transmit power into 100 Ω

Signal type	Maximum aggregate transmit power	Indicative number of carriers (see note)
EC ADL down (clause E.1.1): (derived from ADSL over POTS)	20,4 dBm	254
EC ADL up (clause E.1.3): (derived from ADSL over POTS)	13,3 dBm	31
FDD ADL down (clause E.1.2): (derived from ADSL over POTS)	19,9 dBm	227
FDD ADL up (clause E.1.3): (derived from ADSL over POTS)	13,3 dBm	31
EC ADL down (clause E.2.1): (derived from ADSL over ISDN)	20,4 dBm	254
EC ADL up (clause E.2.3): (derived from ADSL over ISDN)	13,4 dBm	31-63
FDD ADL down (clause E.2.2): (derived from ADSL over ISDN)	19,3 dBm	197
FDD ADL up (clause E.2.3): (derived from ADSL over ISDN)	13,4 dBm	31-63
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.		

Annex F (informative): Example injection method for noise generator [G8]

It is allowed to inject the noise G8 with a voltage source modelling the 4B3T ISDN. This source has a 150Ω output impedance, and is coupled to the line with an actual splitter lowpass. This injection method will model not only the noise, but also the effect of the splitter filters and their impedance on the ADSL system. In this case the PSD of this voltage generator must model the complete signal of the ISDN transceiver, and not the residual noise at the entrance of the ADSL modem as given in table 7. The PSD of the voltage source including its 150 Ωoutput impedance is measured on a 150 Ω termination. It is given by table F.1:

Table F.1: PSD mask for ISDN

f (kHz)	PSD (dBm/Hz)
5	-40
22,5	-36
40	-37
65	-40
80	-43
100	-50
122,5	-62
154.5	-60
170	-61
185	-65
200	-69
215	-74
250	-82
300	-78
400	-67
1 000	-67
5 000	-120

NOTE: The above ISDN PSD corresponds to an average PSD based on measurements of different ISDN 4B3T transceivers. As worst case, 4B3T is used rather than 2B1Q.

History

Document history		
V1.1.1	November 1998	Publication
V1.2.1	October 2001	Publication
V1.3.1	May 2002	Publication