ETSI STC TM6

(ACCESS TRANSMISSION SYSTEMS ON METALLIC CABLES)

Permanent Document TM6(98)10

Laboratory Performance tests for xDSL systems

This is a living document, to be updated every ETSI meeting, when new input arises

This document is intended to keep track of the various proposals in ETSI-TM6 on performance tests for xDSL, that have gained some support. Consensus has grown within ETSI-TM6 to define one unified performance tests for all long range xDSL systems, including SDSL and ADSL, that lines up with the VDSL performance tests. This document is a basis for such a future work item within ETSI-TM6.
The main portion of this document is based on its original version [6] and updated with

- the time domain requirements described in [7],
- the noise models for SDSL described in [8,9,10],
- the noise models for ADSL described in [11], and
- the testloops as described in [15] and preceded by [16,17,18].
- a first description of impulse noise tests
- significant update of ingress noise in figures and text all over the document
- performance objectives for SDSL abd ADSL over ISDN
- test sequences for SDSL
- start with description of VDSL testing
- addition of section dedicated to terminology, plus reshuffle of the structure of the document

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CONTENTS

1. Scope

This document defines laboratory performance tests for various xDSL systems. The tests will stress xDSL transceivers in various ways that are representative to a high penitration of systems scenario in operational access networks. This high penitration approach enables the verification that an xDSL modem under test will meet minimal performance objectives under a wide variety of operational situations.

2. References

<various standards>

3. Definitions and abbreviations

3.1. Definitions and Terminology

Within the context of xDSL performance testing, the following definitions apply:

Disturber or Interferer
System that generates a signal that impairs the victem xDSL modem under test. Usually these are xDSL modems that make use of other wire pairs of the same cable.

Equivalent disturber
Virtual generator, that represents the combined signal from several independend (real) disturbers, on a well defined (virtual or real) location. Representing means here that when all represented disturbers are replaced by this equivalent disturber, the total impairment will be the same. Examples are

- Equivalent NEXT disturber
- Equivalent FEXT disturber
- ..

Noise
Any electrical signal, generated by one or a mixture of disturbers, that is random, harmonic or impulsive in nature, or has a combination of these properties, as it can be observed on a well defined (virtual or real) location.

Crosstalk noise
Noise, originated from disturbers inside the same cable (systems connected to other wire pairs in the same cable).

> ***Self (crosstalk) noise***
> All crosstalk noise related to xDSL disturbers that are of the same type as the xDSL modem under test. It may refer to the noise of an equivalent (self) disturber, self crosstalk noise
>
> ***Alien (crosstalk) noise***

All crosstalk noise related to xDSL disturbers that are of a different type as the xDSL modem under test. It may refer to the noise of an equivalent (self) disturber, self crosstalk noise

Overall (crosstalk) noise
The combination of Self and Alien crosstalk noise, using a weighed power sum

Ingress noise
Noise, originated from disturbers outside the cable (radiating systems, leaking energy into the cable).

Impulse noise
Noise, originated from unidentified disturbers, such as on-hook / off-hook impulses, switching devices, etc.

Impairment
Noise, coupled into the victem wire pair, as it can be observed at the receiver input of victem modem under test. It is the combination of crosstalk noise, ingress noise and Impulse noise

Impairment generator
Instrument, or combination of instruments, that generates all kinds of noise to be fed to the test setup.

Equivalent Noise
Noise, generated by an equivalent disturber. Related definitions are:

- *equivalent crosstalk noise* - equivalent noise originating from disturbers in other wire pairs
  - e.g. generated by an "equivalent self crosstalk disturber"
  - e.g. generated by an "equivalent alien crosstalk disturber"
  - e.g. generated by an "equivalent background noise disturber"
  - e.g. generated by an "equivalent white noise disturber"
- *equivalent ingress noise* - equivalent noise originating from disturbers outside the cable
  - e.g. generated by an "equivalent broadband RFI disturber"
  - e.g. generated by an "equivalent amateur RFI disturber"
- *equivalent Impulse noise* - equivalent noise originating from unidentified disturbers

Noise profile
Formulation to provide a direct specification of how to generate noise for testing purposes. Examples are PSD shapes, crest factor, or frequencies and powers of RFI tones. Examples are:

- crosstalk noise profile
- ingress noise profile
- Impulse noise profile

Noise model
Formulation to provide an indirect specification of how to generate noise for testing purposes. This incluses one or more noise profiles, plus additional computational descriptions like crosstalk coupling functions, power combining, testloop length, etc. Examples are:

- equivalent crosstalk noise model (A,B,C)
- equivalent ingress noise model
- equivalent impulse noise model

***Reference impedance* (135 Ω)**
A pure resistive load impedance that is used to normalize the way signal levels are to be measured and specified. The reference impedance $\mathbf{R_V}$ is 135Ω for all xDSL performance tests. This reference impedance is not related to the design impedance for the various xDSL systems, such as 100Ω for ADSL, or 135Ω for SDSL, HDSL and VDSL. The reason for choosing a common reference impedance for all xDSL performance test is to harmonize test equipment, to simplify their calibration and to unify the way they should display there measured results.

PSD
Power spectral Density. Unsless specified otherwise, the PSD represents the single sided power spectral density of a signal under test, terminated by the reference impedance of 135Ω.

Various
- Crest factor
- NEXT
- FEXT
- testloop

3.2. Abbreviations

4. Test procedure

The purpose of this sub-clause is to provide an unambiguous specification of the test set-up, the insertion path and the way signal and noise levels are defined. The tests are focused on the noise margin, with respect to the crosstalk noise or impulse noise levels when xDSL signals under test are attenuated by standard test-loops and interfered with standard crosstalk noise or impulse noise. This noise margin indicates what increase of crosstalk noise or impulse noise level is allowed under (country-specific) operational conditions to ensure sufficient transmission quality.

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

4.1. Test set-up definition

Figure 1 illustrates the functional description of the test set-up. It includes:
- A bit error ratio test set (BERTS) that applies a 2^{15}–1 pseudo random bit sequence (PRBS) test signal to the transmitter in the direction under test at the bitrate required. The transmitter in the opposing direction shall be fed with a similar PRBS signal, although there is no need to monitor the reconstructed signal in this path.
- The test loops, as specified in sub-clause 5.
- An adding element to add the (common mode and differential mode) impairment noise (a mix of random, impulsive and harmonic noise), as specified in sub-clause 6.
- An impairment generator, as specified in sub-clause 6, to generate both the differential mode and common mode impairment noise, that are fed to the adding element.
- A high impedance, and well balanced differential mode voltage probe (e.g. better than 60 dB across the whole band of the xDSL system under test) connected with level detectors such as a spectrum analyser or a true rms voltmeter.
- A high impedance, and well balanced common mode voltage probe (e.g. better than 60 dB across the whole band of the xDSL system under test) connected with level detectors such as a spectrum analyser or a true rms voltmeter.

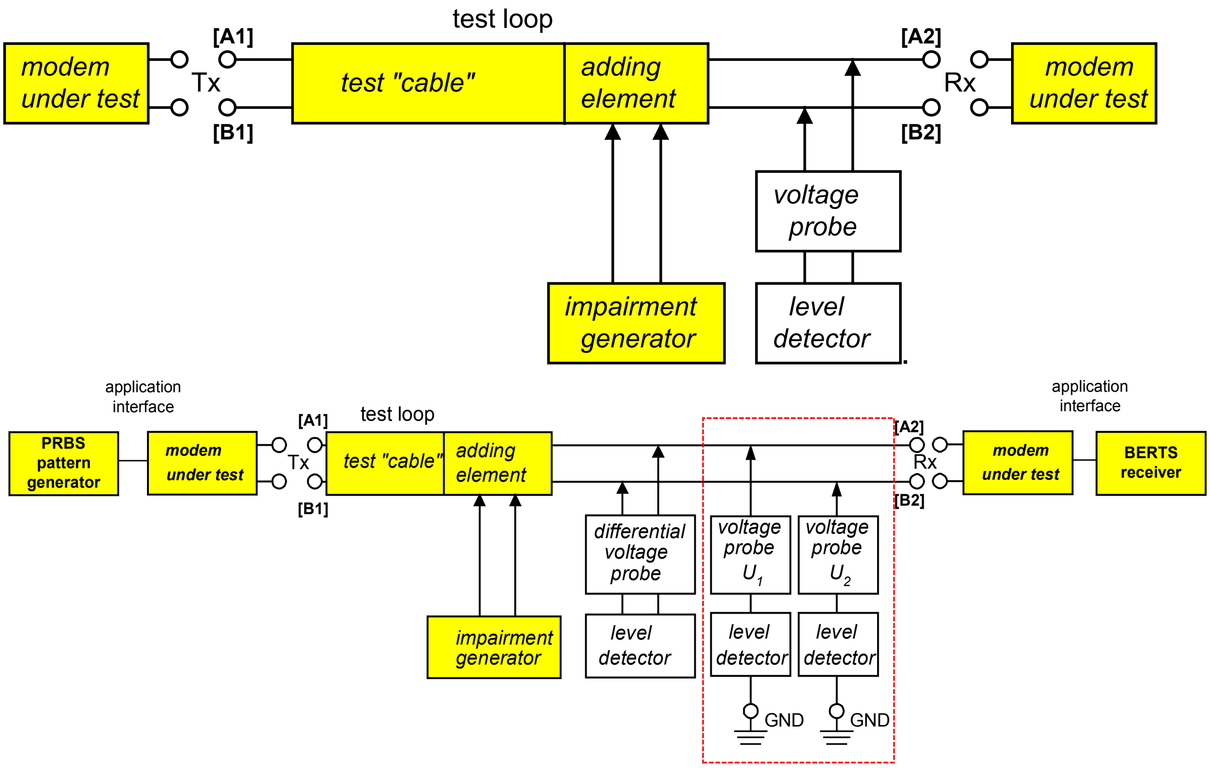


Figure 1: Functional description of the set-up of the performance tests. When external splitters are required for the xDSL system under test (for POTS or ISDN signals), this splitter shall be included in the modem under test.

ED More details about grounding has to be added here

The two-port characteristics (transfer function, impedance) of the test-loop, as specified in sub-clause 5, are defined between port Tx (node pairs A1,B1) and port Rx (node pair A2,B2). The consequence is that the two-port characteristics of the test "cable" in Figure 1 must be properly adjusted to take full account of non-zero insertion loss and non-infinite shunt impedance of the adding element and impairment generator. This is to ensure that the insertion of the generated impairment signals does not appreciably loads the line.

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

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 the level, measured between node A2 and B2, when port Tx as well as port Rx are terminated with the xDSL transceivers under test. The impairment generator is switched off during this measurement.

Test Loop #0, as specified in sub-clause 5, shall always be used for calibrating and verifying the correct settings of generators G1-G7, as specified in sub-clause 6, when performing performance tests.

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

The impairment noise shall be a mix of random, impulsive and harmonic noise, as defined in sub-clause 6. The level that is specified in sub-clause 6 is the level at port Rx, measured between node A2 and B2 (and includes both differential mode and common mode impairments), while port Tx as well as port Rx are terminated with the normalized test impedance $\mathbf{R_V}$. These impedances shall be passive when the transceiver impedance in the switched-off mode is different from this value.

4.2. Startup training procedure

> **ED NOTE** <for further study>. Let's make a description for modem startup training at noise levels that are 10 dB below the test noise. This verifies how adequate an activated the modem will respond to noise levels that vary in time (non-stationary crosstalk). See also the Alcatel contribution to the Sophia meeting: 985t37a0 and 985t38a0

4.3. Signal and noise level definitions

The differential mode signal and noise levels are probed with a well balanced differential voltage probe (U_2–U_1). The differential impedance between the tips of that probe shall be higher than the shunt impedance of 100 kΩ in parallel with 10 pF. Figure 1 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 common mode signal and noise levels are probed with a well balanced common mode voltage probe as the voltage between nodes A2, B2 and ground. Figure 1 shows the position of the two voltage probes when measuring the common mode signal. The common mode voltage is defined as $(U_1+U_2)/2$.

NOTE: The various levels (or spectral masks) of signal and noise that are specified in this document are defined at the Tx or Rx side of this set-up. The various levels are defined while the set-up is terminated, as described above, with normalized test impedance $\mathbf{R_V}$ or with xDSL transceivers under test.

Probing an rms-voltage U_{rms} [V] in this set-up, over the full signal band, means a power level of P [dBm] that equals:
$P = 10 \times \log_{10} (U_{rms}^2 / R_V \times 1000)$ [dBm]

Probing an rms-voltage U_{rms} [V] in this set-up, within a small frequency band of Δf (in Hertz), means an average spectral density level of P [dBm/Hz] within that filtered band that equals:
$P = 10 \times \log_{10} (U_{rms}^2 / R_V \times 1000 / \Delta f)$ [dBm/Hz]

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

5. Test loops

The purpose of the test loops shown in Figure 1 is to stress xDSL transceivers under a wide range of different conditions that can be expected when deploying xDSL in real access networks

5.1. Functional description

The test loops in section 5.2 are an artificial mixture of cable sections. A number of different loops has been used to represent a wide range of cable impedances, and to represent ripple in amplitude and phase characteristics of the testloop transfer function.

- The length of the individual loops are such chosen that the transmission characteristics of all loops are comparable. This has been achieved by normalizing the *electrical* length of the loops (insertion loss at a well chosen test frequency). The purpose of this is to stress the equalizer of the xDSL modem under test similarly over all loops, when testing xDSL at a specific bitrate. The total length of each loop is described in terms of *physical* length, and the length of the individual sections as a fixed fraction of this total. If implementation tolerances of one testloop causes that its resulting *electrical* length is out of specification, then its total physical length shall be scaled accordingly to correct this error.
- The impedance characteristics of these loops are such chosen that they cover 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 echo cancelation of the xDSL modem under test. This effect has been emphasized by implementing some loops with highly mismatched cable sections.
- Some test loops include bridged taps to achieve rapid variations in amplitude and phase characteristics of the cable transfer function. In some European access networks, these bridge taps have been implemented in the past, which stresses the xDSL modem under test differently.

5.2. Testloop topology

The loops are defined as a combination of cable sections. Each section is defined by means of two-port cable models of the individual sections (see Annex [*]). Cable simulators as well as real cables can be used for these sections. The length of the individual loops are defined by the tables of section 7.

> **ED NOTE** Currently, different testloops are being used for testing ADSL, HDSL and VDSL. For the short term, SDSL has adopted existing HDSL testloops. There is consensus within ETSI-TM6 that this situation needs to be improved in future by one common unified approach. The definition of unified testloops is currently under study.

5.2.1. SDSL Testloops

The topology of the SDSL loops is specified in figure 2. The transfer function of all the loops for each payload bit-rate is shown in figure 3. The variation of input impedance for the various test loops is shown in figure 4. The two-port cable models that are used to describe the individual sections of the loops are specified in Annex A.2.

- Loop #1 is a symbolic name for a loop with zero (or near zero) length, to prove that the SDSL transceiver under test can handle the potentially high signal levels when two transceivers are directly interconnected.
- The other loops are copied from the HDSL tests.

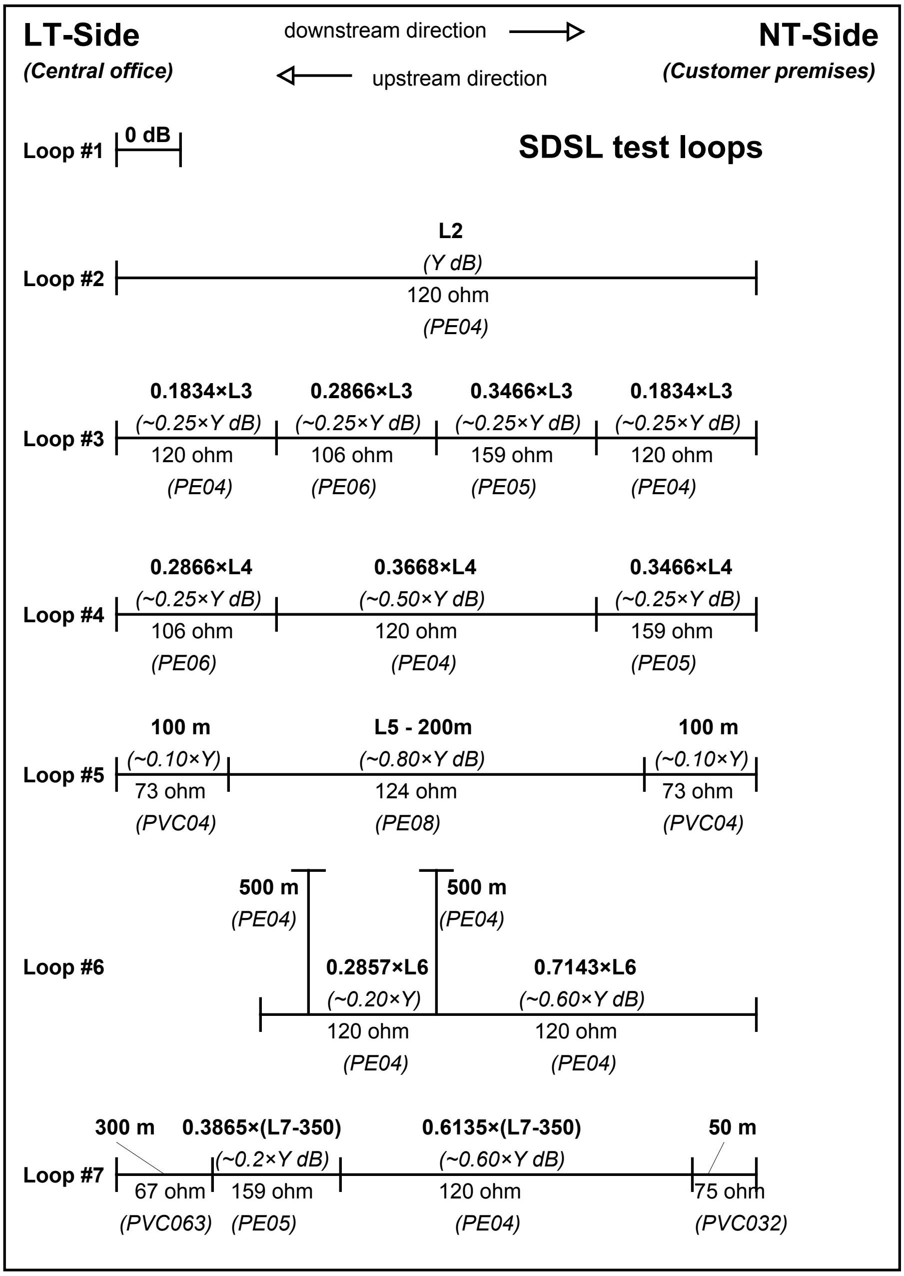


Figure 2: Test loop topology for SDSL, that is made as similar as possible to existing HDSL test loops. The physical lengths L1 to L7 are specified in table 12. The symbolic labels (e.g. "PE04") refer to the two-port cable models that are specified in Annex A. The impedances refer to the characteristic impedance of each section, at 300 kHz, and is for information only. The same applies to the "Y"-values, that refer to what portion of the characteristic insertion loss is accounted for each section.

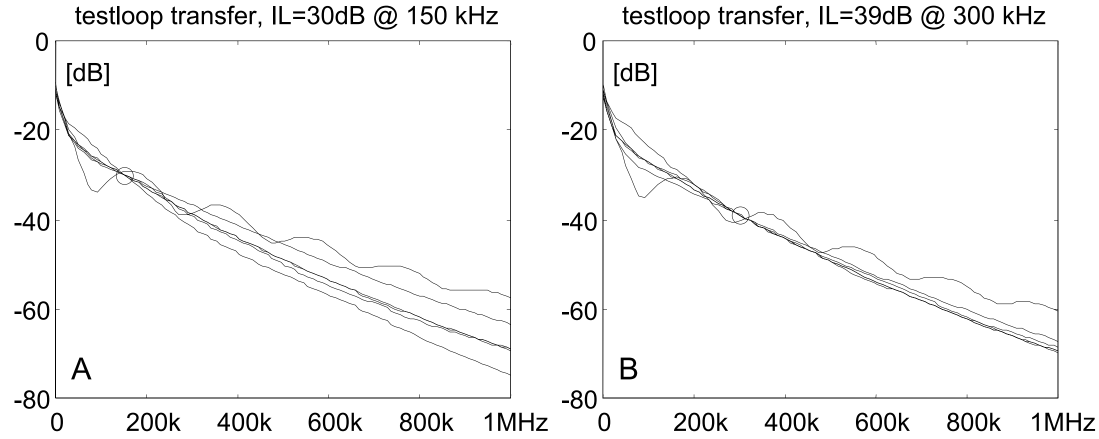


Figure 3: Examples of calculated transfer functions (into 135Ω) of test-loop #2 to #7, (and #8 as the reversed loop #4). In figure 3a the electrical length of each loop is normalized at 150 kHz (30 dB loss in this example), and in figure 3b at 300 kHz (39 dB in this example). The choise for test frequencyies, as specified in table 12, is closely related to the PSD of the xDSL modem under test, and this PSD may vary with the payload bitrate.

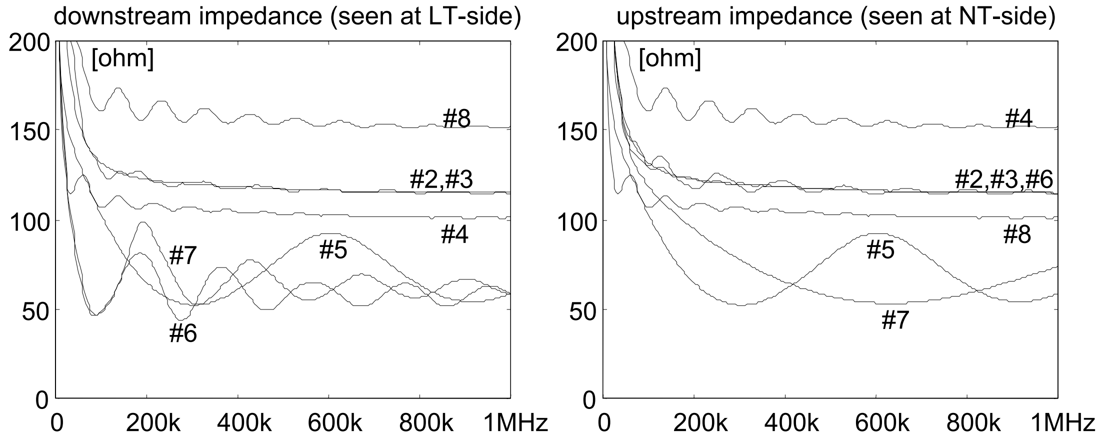


Figure 4: Calculated variation of input impedance (absolute value) of testloop #2 to #8. When the cable is relatively long, these impedances become more or less length independent.

5.2.2. ADSL Testloops

The topology of the ADSL loops is specified in figure 5. The two-port cable models that are used to describe the individual sections of the loops are specified in Annex A.3.

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.

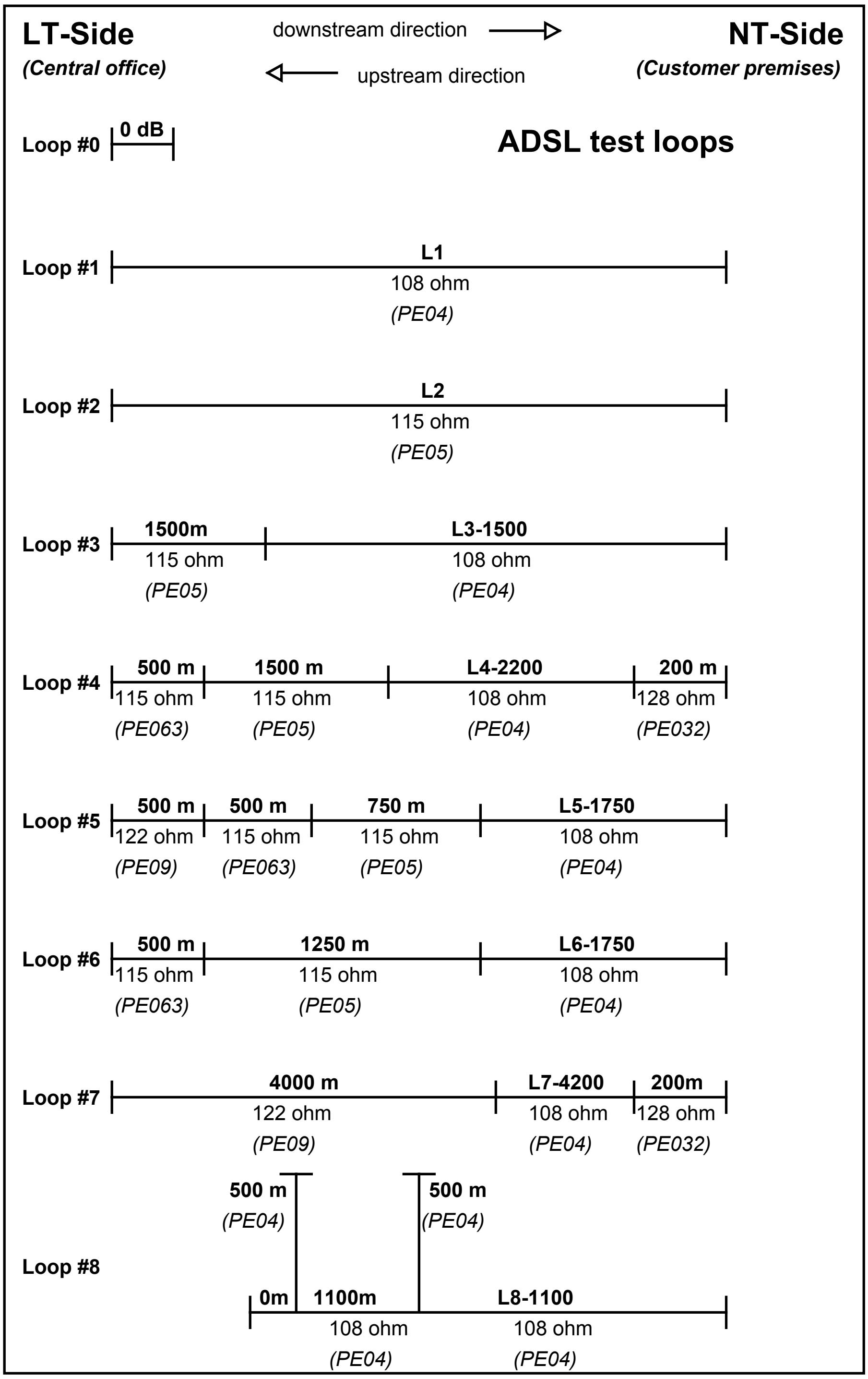


Figure 5: Test loop topology for ADSL

5.2.3. VDSL Testloops

ED NOTE To be inserted here in a future update of this document

5.2.4. Unified Testloops

ED NOTE This subject is for further study

The topology of the unified loops is specified in figure 6. The transfer function of all the loops for each payload bit-rate is shown in figure 7. The variation of input impedance for the various test loops is shown in figure 8. The two-port cable models that are used to describe the individual sections of the loops are specified in Annex A.4.

- Loop #0 is a symbolic name for a loop with zero (or near zero) length, to prove that the xDSL transceiver under test can handle the potentially high signal levels when two transceivers are directly interconnected.
- The impedances of Loop #1 and #2 are nearly constant over a wide frequency interval. These two loops represent uniform distribution cables, one having a relatively low characteristic impedance and another having a relative high impedance (low capacitance per unit length). These impedance values are chosen to be the lowest and highest values of distribution cables that are commonly used in Europe.
- The impedances of Loop #3 and #4 follow frequency curves that are oscillating in nature. This represents the mismatch effects in distribution cables caused by a short extent with a cable that differs significantly in characteristic impedance. Loop #3 represents this at the LT side to stress downstream signals. Loop #4 does the same at the NT side to stress upstream signals.
- Loop #5 is a loop with bridged taps. Details for this loop are for further study.

All other test loops in Figure 6 have equal *electrical* length (insertion loss at a specified test frequency), but differ in input impedance (see Figure 8). It are these values for insertion loss and impedance that define an actual test loop set. The loops are not defined in terms of a specific *physical* length.

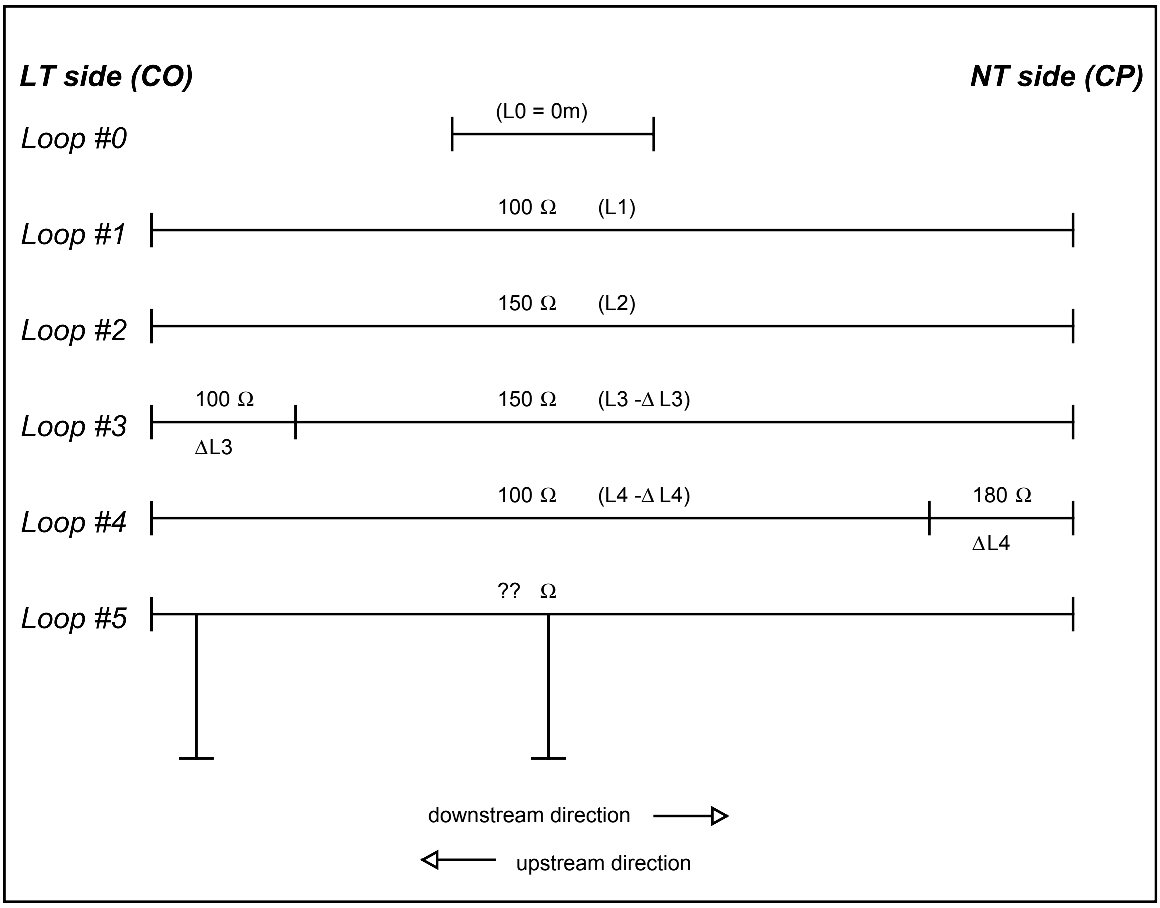


Figure 6: Test loop topology

The variation of input impedance for the various test loops is shown in Figure 8. The transfer function of all the loops for each payload bit-rate is shown in Figure 7.

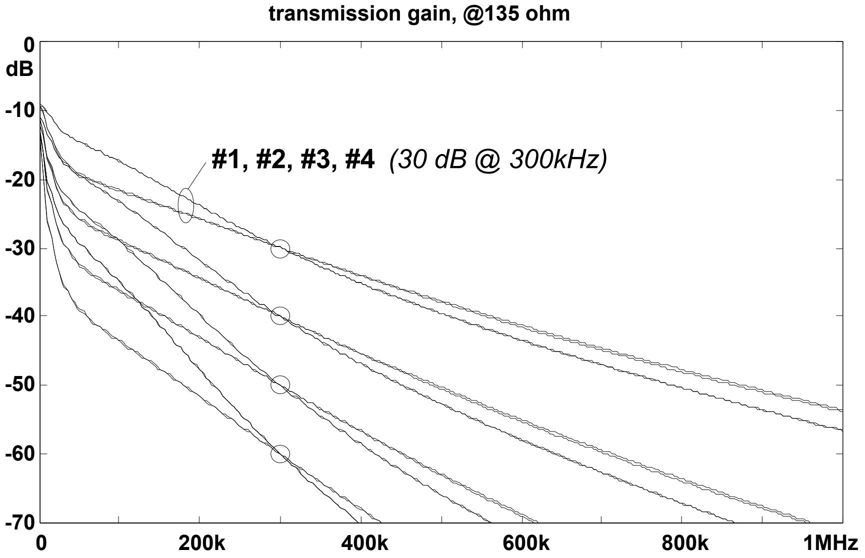


Figure 7: Transmission gain (in 135Ω) of the test-loops, for different electrical lengths (= insertion loss, @300kHz, @135Ω). Loop #1 and #4 are very similar in transmission gain; the same applies to loop #2 and #3, but their difference is small due to the normalization at 300 kHz.

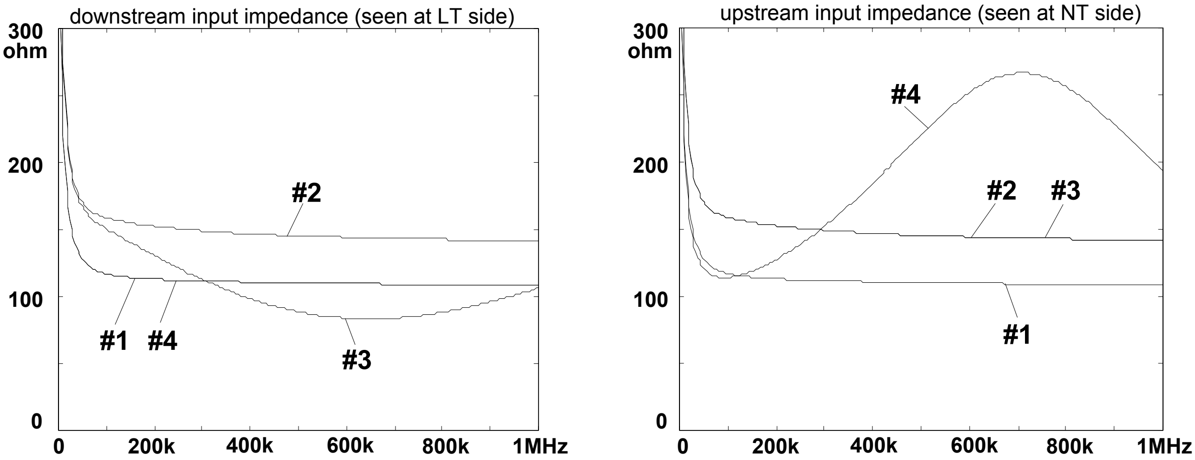


Figure 8: Calculated variation of input impedance (absolute value) of long testloops (≈6 km)

5.3. Testloop accuracy

The different cable sections in the topology of Figure 1 are specified by two-port cable models that serve as a template for real twisted-pair cables. Cable simulators as well as real cables can be used for these test loops. The associated models and line constants are specified in Annex A.

The characteristics of each testloop, with cascaded sections, shall approximate the models within a specified accuracy. This accuracy specification does not hold for the individual sections.

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

- The group delay of the test-loop shall approximate the group delay of the specified cascaded models within 3% on a linear scale, between 0,1×f_T and 6×f_T.

The *electrical* length (insertion loss at specified test frequency), specified in table 12, is mandatory. If implementation tolerances of one testloop causes that its *electrical* length is out of specification, its total *physical* length shall be scaled accordingly to adjust this error.

6. Impairment generator

The impairment generator, generates the noise that is to be injected into the test setup, including crosstalk noise, ingress noise and impulse noise.

The crosstalk noise that is to be generated is frequency dependent, is dependent on the length of the testloop and is also different for downstream performance tests and upstream performance tests. In addition, different crosstalk noise models are defined. As a result, different test sequences require different cross talk noise characteristics. For an example on how the generated spectrum of the impairment may look like, see clause [*].

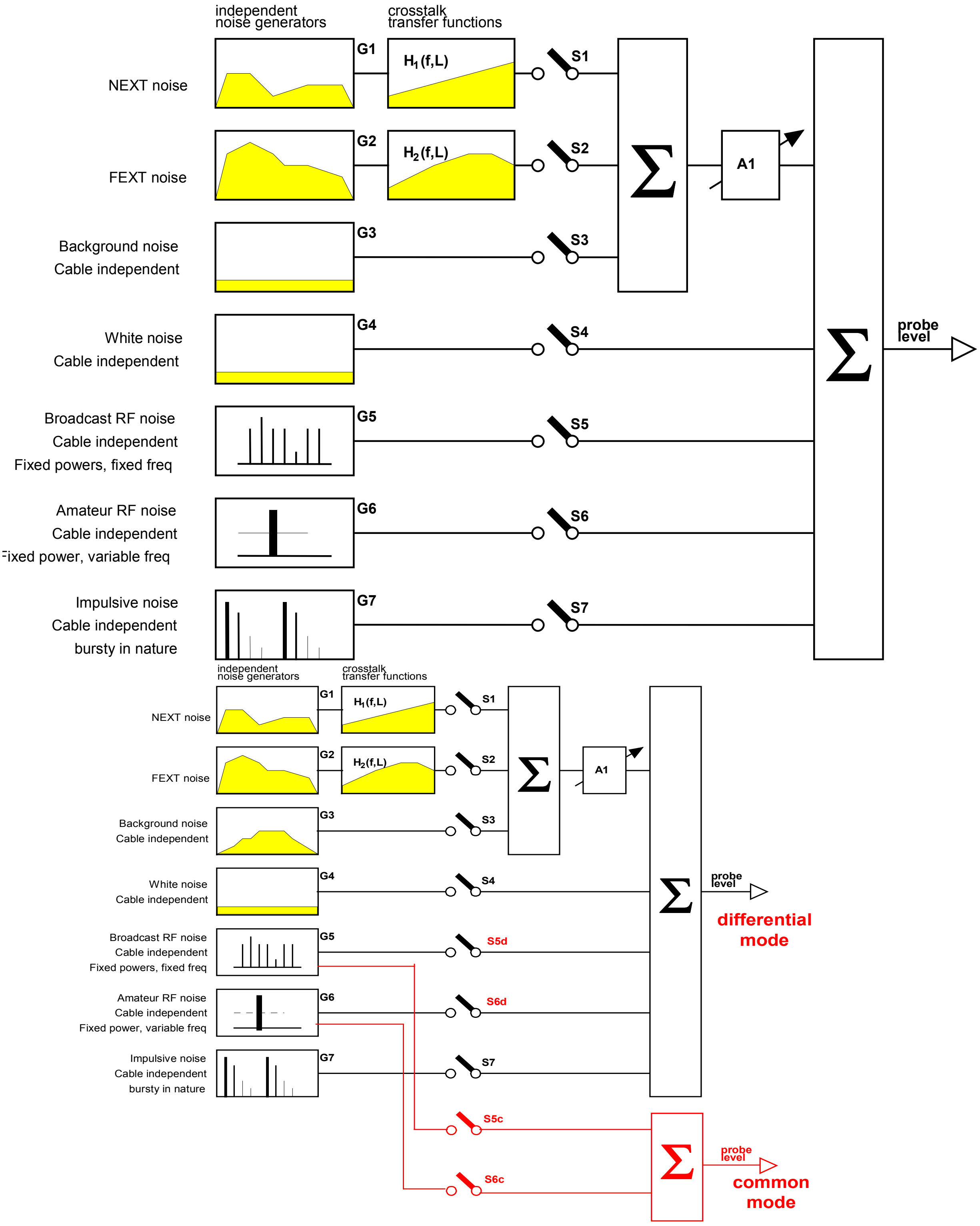
The definition of the impairment noise for xDSL performance tests is therefore very complex and for the purposes of this TS it has been broken down into smaller, more easily specified components. These components include equivalent disturbers and crosstalk coupling functions. These separate, and uncorrelated, equivalent disturbers may therefore be isolated and summed to form the impairment generator for the xDSL system under test. The detailed specifications for the components of the noise model(s) are given in this sub-clause, together with a brief explanation.

6.1. Functional description

Figure 9 defines a functional diagram of the composite impairment noise. It defines a functional description of the combined impairment noise, as it must be probed at the receiver input of the xDSL transceiver under test. This probing is defined in sub-clause 4.3.
The functional diagram has the following elements:

- The seven impairment “generators” G1 to G7 generate noise as defined in sub-clause 6.3.1 to 6.3.7. Their noise characteristics are independent from the test-loops and bit-rates.
- The transfer function $H_1(f,L)$ models the length and frequency dependency of the NEXT impairment, as specified in sub-clause 6.2. The transfer function is independent of the loop-set number, but changes with the electrical length of the test loop. Its transfer function changes with the frequency *f*, roughly according to $f^{0.75}$.
- The transfer function $H_2(f,L)$ models the length and frequency dependency of the FEXT impairment, as specified in sub-clause 6.2. Its transfer function is independent of the loop-set number, but changes with the electrical length of the test loop. Its transfer function changes with the frequency *f*, roughly according to *f* times the cable transfer function.
- Switches S1-S7 determine whether or not a specific impairment generator contributes to the total impairment during a test.
- Amplifier A1 models the property to increase the level of some generators simultaneously to perform the noise margin tests as defined in sub-clause 8.2. A value of **x** dB means a frequency independent increase of the level by **x** dB over the full band of the xDSL system under test, from f_L to f_H. Unless otherwise specified, its gain is fixed at 0 dB.

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. These function blocks may be incorporated with the test-loop and the adding element as one integrated construction.
The average transfer function $s_{T0}(\omega,L)$ of the four test-loops is the s_{21} transfer function parameter in source/load resistance $\mathbf{R_V}$ of test-loop #1 at specified payload bit-rate. It is considered as an average of all the four loops at equal electrical length (normalised in insertion loss at a specified test frequency).



NOTE 1: Generator G7 is the only one which is symbolically shown in the time domain.
NOTE 2: The precise definition of impulse noise margin is for further study.

Figure 9: Functional diagram of the composition of the impairment noise

This functional diagram will be used for impairment tests in downstream and upstream direction. Several scenario's have been identified to be applied to xDSL testing. These scenario's are intended to be representative of the impairments found in metallic access networks.
Each scenario (or noise model) results in a length dependent PSD description of noise. Each noise model is subdivided into two parts: one to be injected at the LT-side, and another to be

injected at the NT-side of the xDSL modem link under test. Some of the seven individual impairment “generators” G1 to G7 are therefore defined by more than one noise model.

Each test has its own impairment specification, as specified in clause 8. The overall impairment noise shall be characterised by the sum of the individual components as specified in the relevant sub-clauses. This combined impairment noise is applied to the receiver under test, at either the LT (for upstream) or NT (for downstream) ends of the test-loop.

6.2. Cable cross-talk models

The purpose of the cable cross-talk models is to model both the length and frequency dependence of crosstalk measured in real cables. These cross-talk transfer functions adjust the level of the noise generators in Figure 9 when the electrical length of the test-loops is changed. 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:

- Variable **f** identifies the frequency in Hertz.
- Constant **f_0** identifies a chosen reference frequency, which was set to 1 MHz.
- Variable **L** identifies the physical length of the actual test loop in meters. This physical length is calculated from the cable models in annex A, from the specified electrical length. Value are summarized in table 12 for each combination of payload bitrate, noise model and test loop.
- Constant **L_0** identifies a chosen reference length, which was set to 1 km.
- Transfer function **$s_T(f, L)$** represents the frequency and length dependent amplitude of the transfer 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 135Ω. Annex A provides formula’s to calculate this s-parameter.
- Constant **K_{xn}** identifies an empirically obtained number that scales the NEXT transfer function $H_1(f, L)$. The resulting transfer function represents a power summed cross-talk model [*] of the NEXT as it was observed in a test cable. Although several disturbers and wire pairs were used, this function $H_1(f, L)$ is scaled down as if it originates from a single disturber in a single wire pair.
- Constant **K_{xf}** identifies an empirically obtained number that scales the FEXT transfer function $H_2(f, L)$ The resulting transfer function represents a power summed cross-talk model [*] of the FEXT as it was observed in a test cable. Although several disturbers and wire pairs were used, this function $H_2(f, L)$ is scaled down as if it originates from a single disturber in a single wire pair.

The transfer functions in Table 1 shall be used as cross-talk transfer functions in the impairment generator.

$$H_1(f, L) = K_{xn} \times (f/f_0)^{0.75} \times \sqrt{1 - |s_T(f, L)|^4}$$

$$H_2(f, L) = K_{xf} \times (f/f_0) \times \sqrt{(L/L_0)} \times |s_T(f, L)|$$

$K_{xn} = 10^{(-50/20)} \approx 0.0032,\ f_0 = 1\text{ MHz}$

$K_{xf} = 10^{(-45/20)} \approx 0.0056,\ L_0 = 1\text{ km}$

$s_{T0}(f, L)$ = averaged test loop transfer function

Table 1 : Definition of the crosstalk transfer functions

6.3. Individual impairment generators

6.3.1. Equivalent NEXT disturbance generator [G1.xx]

The NEXT noise generator represents the equivalent disturbance of all impairment that is identified as crosstalk noise from a predominantly Near End origin. This noise, filtered by the NEXT crosstalk coupling function of sub-clause 6.2, will represent the contribution of all NEXT to the composite impairment noise of the test.

The PSD of this noise generator is one of the PSD profiles, defined in sub-clause 6.4. For testing upstream and downstream performance, different PSD profiles are to be used, as specified below.

G1.UP.# = X.LT.# = (XS.LT.# ♦ XA.LT.#)
G1.DN.# = X.NT.# = (XS.NT.# ♦ XA.NT.#)

The symbols in this expression, refer to the following:

- Symbol “#” is a placeholder for noise model “A”, “B” , “C” or “D”.
- Symbol “X.LT.#” and “X.NT.#” refers to the <u>overall</u> crosstalk profile, as defined in 6.4.
- Symbol “XS.LT.#” and “XS.NT.#” refers to the <u>self</u> crosstalk profile, as defined in 6.4.
- Symbol “XA.LT.#” and “XA.NT.#” refers to the <u>alien</u> crosstalk profile, as defined in 6.4.
- Symbol “♦” refers to the FSAN crosstalk sum of two PSD”s. This FSAN crosstalk sum is defined as $P_X = (P_{XS}^{Kn} + P_{XA}^{Kn})^{1/Kn}$, where P denotes the PSD’s in W/Hz, and K_n=1/0.6.

In the case that the overall crosstalk noise is defined as the combination of self crosstalk and alien crosstalk, a weighed sum “♦” of two individually defined profiles has to be evaluated.

This PSD is not related to the cable because the cable portion is modelled separately as transfer function $H_1(f,L)$, as specified in sub-clause 6.2.

The noise of this noise generator shall be uncorrelated with all the other noise sources in the impairment generator, and uncorrelated with the xDSL system under test. The noise shall be random in nature and near Gaussian distributed, as specified in sub-clause 6.4.4.

6.3.2. Equivalent FEXT disturbance generator [G2.xx]

The FEXT noise generator represents the equivalent disturbance of all impairment that is identified as crosstalk noise from a predominantly Far End origin. This noise, filtered by the FEXT crosstalk coupling function of sub-clause 6.2, will represent the contribution of all FEXT to the composite impairment noise of the test.

The PSD of this noise generator is one of the PSD profiles, defined in sub-clause 6.4. For testing upstream and downstream performance, different PSD profiles are to be used, as specified below.

G2.UP.# = X.NT.# = (XS.NT.# ♦ XA.NT.#)
G2.DN.# = X.LT.# = (XS.LT.# ♦ XA.LT.#)

The symbols in this expression, refer to the following:

- Symbol “#” is a placeholder for noise model “A”, “B”, “C” or “D”.
- Symbol “X.LT.#” and “X.NT.#” refers to the <u>overall</u> crosstalk profiles, as defined in 6.4.
- Symbol “XS.LT.#” and “XS.NT.#” refers to the <u>self</u> crosstalk profiles, as defined in 6.4.
- Symbol “XA.LT.#” and “XA.NT.#” refers to the <u>alien</u> crosstalk profiles, as defined in 6.4.
- Symbol “♦” refers to the FSAN crosstalk sum of two PSD”s. This FSAN crosstalk sum is defined as $P_X = (P_{XS}^{Kn} + P_{XA}^{Kn})^{1/Kn}$, where P denotes the PSD’s in W/Hz, and K_n=1/0.6.

In the case that the overall crosstalk noise is defined as the combination of self crosstalk and alien crosstalk, a weighed sum “♦” of two individually defined profiles has to be evaluated.

This PSD is not related to the cable because the cable portion is modelled separately as transfer function $H_2(f,L)$, as specified in sub-clause 6.2.

The noise of this noise generator shall be uncorrelated with all the other noise sources in the impairment generator, and uncorrelated with the xDSL system under test. The noise shall be random in nature and near Gaussian distributed, as specified in sub-clause 6.4.4.

6.3.3. Equivalent background noise generator [G3]

The background noise generator is Inactive and set to zero.

6.3.4. Equivalent white noise generator [G4]

The white noise generator has a fixed, frequency independent value, and is set to –140 dBm/Hz into 135 Ω. The noise of this noise generator shall be uncorrelated with all the other noise sources in the impairment generator, and uncorrelated with the xDSL system under test. The noise shall be random in nature and near Gaussian distributed, as specified in sub-clause 6.4.4.

6.3.5. Equivalent 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 figure 9, generator G6) because their carrier is not suppressed. Ingress causes differential mode as well as common mode interference.
Power levels of up to –40 dBm can occur on telephone lines in the distant vicinity of broadcast AM transmitters. The noise is typically dominated by the closest 10 or so transmitters to the victim wire pair.

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

$$U(t) = \sum_{\mathbf{k}} U_k \times cos(2\pi \cdot f_k \times t + \varphi_k) \times (1 + m \times \alpha_k(t))$$

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

- $\boldsymbol{U_k}$ - The voltage U_k of each individual carrier is specified in table 2 as power level P (dBm) into a resistive load of R=135Ω. Mark that spectrum analysers will detect levels that are slightly higher then the values specified in table 2 when their resolution band width is set to 10 kHz or more, since they will detect the modulation power as well.
- $\boldsymbol{f_k}$ - The frequency f_k of each individual carrier is specified in table 2. Their values do not represent actual broadcast frequencies but they are chosen in such a way that they cover a frequency range that is relevant for the xDSL modem under test, and that the harmonic relation between the carriers 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 each 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 $m \times \alpha_k(t)$ having a crestfactor of 2,5.
- $\boldsymbol{\alpha_k(t)}$ - The normalized modulation noise $\alpha_k(t)$ of each individually modulated carrier shall be random in nature, shall be Gaussian distibuted in nature, shall have an RMS value of α_{rms}=1, shall have a crest factor of 2,5 or more, and shall be uncorrelated with the modulation noise of each other modulated carrier in the ingress noise signal.
- $\boldsymbol{\Delta b}$ - The modulation width Δb of each modulated carrier shall be at least 2×5 kHz. This is equivalent to creating $\alpha_k(t)$ from white noise, filtered by a low-pass filter having its cut-off frequency at $\Delta b/2$ = 5 kHz. This modulation width covers the full modulation band used by AM broadcast stations.

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

NOTE. The question if the differential mode and common mode signals are (partly) correlated or fully uncorrelated is ***for further study***. The rapid fluctuations in the frequency domain of cable balance in real cables may give rise to fully uncorrelated differential and common mode ingress noise.

Ed. For further study. Its to be expected that the carier frequencies below 1 MHz, as specified in the VDSL functional requirements, are suitable for SDSL too. Since the SDSL testloops are significantly longer than the VDSL testloops, its expected that the levels of these carrier frequencies must be higher than specified for VDSL.

In ETR 328 (The ETSI ADSL report from nov 1996), the following values for RFI ingress noise are defined.

frequency	99	207	333	387	531	603	711	801	909	981	kHz
power	–70	–70	–70	–70	–70	–70	–70	–70	–70	–70	dBm

In WD24 from Villach, the following values for RFI ingress noise were proposed as a basis for further study

frequency	99	207	333	387	531	603	711	801	909	981	kHz
power	–70	–40	–50	–60	–50	–60	–50	–40	–40	–70	dBm

In TD33 from Edinburgh, the following values for RFI ingress noise were proposed for ADSL, being equal to G992.1

frequency	99	207	333		531	603	711	801	909	981	1458	kHz
power	–70	–50	–60		–40	–60	–60	–60	–40	–70	–40	dBm

In TD33 from Edinburgh, the following values for RFI ingress noise were proposed for ADSL, being equal to G992.2

frequency	99	207	333	387	531	603	711	801	909	981	kHz
power	–70	–40	–60	–60	–40	–50	–60	–50	–40	–60	dBm

In TD35 from Edinburgh, the following values for RFI ingress noise were proposed for SDSL

frequency	99	207	333	387	531	603	711	801	909	981	kHz
power	–70	–40	–60	–60	–40	–50	–40	–50	–60	–60	dBm

In TD34 from Amsterdam, the following values for RFI ingress noise were proposed for SDSL as well as ADSL. It makes a distiction between differen

tial mode ingress, and common mode ingress (not yet covered by the description of the impairment generator

frequency	90	180	360	540	630	720	810	900	1080	1440	kHz
power diff	–70	–50	–60	–40	–60	–60	–60	–40	–70	–40	dBm
power com	–30	–10	–20	–10	–30	–30	–30	–10	–40	–10	dBm
Δ	*40*	*40*	*40*	*30*	*30*	*30*	*30*	*30*	*30*	*30*	*dB*

In WD12 from Montreux, the following values for RFI ingress noise were proposed by Nortel for SDSL as well as ADSL. It makes a distinction between differential mode ingress, and common mode ingress (not yet covered by the description of the impairment generator

frequency	99	207	333	387	531	603	711	801	909	981	kHz
power diff	–70	–50	–60	–60	–40	–60	–60	–40	–70	–40	dBm
power com	–30	–10	–20	–30	–10	–30	–30	–10	–40	–10	dBm
Δ	*40*	*40*	*40*	*30*	*30*	*30*	*30*	*30*	*30*	*30*	*dB*

In TD35 from Vienna, the following values for RFI ingress noise were proposed by Infineon for SDSL; common mode levels are derived from these according to TD37 from Infineon

frequency	99	207	333	387	531	603	711	801	909	981	kHz
power diff	–85	–50	–90	–85	–60	–50	–50	–60	–60	–60	dBm
power com											dBm
Δ	*50*	*45*	*45*	*35*	*35*	*40*	*40*	*40*	*40*	*40*	*dB*

In TD26 from Monterey, BT provides result from RFI ingress measurements. The highest levels observed on rural overhead line "L535" was close to –40dBm in 1 kHz bandwidth

In TD43 from Monterey, the following values for RFI ingress noise were proposed by Infineon for SDSL; common mode levels are derived from these according to TD37 from Infineon

frequency	99	207	333	387	531	603	711	801	909	981	kHz
power diff	–85	–50	–85	–85	–50	–50	–50	–50	–50	–50	dBm
power com											dBm
Δ											*dB*

ED NOTE As can be concluded from the above text, this topic is still for further study within ETSI-TM6. The refered levels are indicative for the variety of thought about it.

Table 2 : Definition of the RFI tones of the ingress noise

6.3.6. Equivalent amateur RF noise generator [G6]

Ed. Is there any need for this in the SDSL frequency band?. The associated carrier frequencies in the functional requirements for VDSL start at 1.8 MHz, which is far above the SDSL frequency band.

6.3.7. Equivalent impulse noise generator [G7]

A test with this noise generator is required to prove the implementation of the forward error correcting coder, which is specified to give some protection from Impulse noise. The impulse noise generator shall generate bursts of noise injected onto the line with sufficient power to ensure effective erasure of the data for the period of the burst.

Tests using this generator are to stress a FEC coder, currently specified as a RS block code with interleaving; there is no intention that the noise bursts are statistically representative of real noise. For realistic statistical models, see Annex C.

Two parameters are specified in this document, related to the length of the "on" and "off" state of the generated bursts. A third parameter is specified, related to their amplitude.

- T1 being the minimum length of isolated noise burst the coder shall always correct, and
- T2 being the maximum recovery time the coder shall need before it treats a succeeding noise burst as isolated from any predecessor burst.
- P_b being the power level for the test noise bursts (see below) at which effective erasure of the data for the period of the burst is to be expected. (the bit error ratio during the burst should be approximately 0.5.)

Immunity shall be demonstrated on short and long loops, in the presence of noise to model cross-talk and RFI. The parameter values are specified in table 3. Further test details are given in sub-clause 8.

The impulse noise generator shall generate bursts of Additive White Gaussian Noise injected onto the line with power P_b. Each noise burst shall be T1 long. The noise bursts shall be applied regularly with a spacing of T2.

T1	<TBD>	s
T2	1	s
P_b	<TBD>	dBm

Table 3 : Definition of the impulse noise parameters

ED NOTE For more information, see TD55 (Helsinki), 002t55.pdf

6.4. Profiles of the equivalent disturbers G1 and G2

This sub clause specifies the noise profiles for the equivalent NEXT and FEXT disturbers (G1 and G2, see figure 9) in the frequency domain (spectrum) as well in the time domain (crest-factor, distribution function) Their noise level originate from a mixture of many disturbers in a real scenario, as if all disturbers are virtually colocated at the ends of the testloops.
This equivalent disturbance, filtered by the NEXT and FEXT coupling functions (see figure 9), will represent the crosstalk noise that is to be injected in the test setup. This approach has isolated their definition from the NEXT and FEXT coupling functions of the cable.

The profiles can specify the equivalent crosstalk disturber directly (in one step) or indirectly (in two steps) by combining an equivalent ***self*** crosstalk disturber and an equivalent ***alien*** crosstalk disturber. The indirect way is more complicated but gives more flexibility, by:

- grouping all disturbers that are similar to the xDSL modem under test (=self disturbers) into one equivalent disturber, and by
- grouping all disturbers that are different from the xDSL modem under test (=alien disturbers) into one equivalent disturber

For xDSL testing, several models for crosstalk noise have been defined. They are different in the technology mixture that has been grouped to define the spectral of the equivalent NEXT and FEXT disturbers.

The naming convention for the spectral profiles of the equivalent NEXT and FEXT disturbers is as follows:

- The profiles (X.LT.#) or in this section describe the total *equivalent disturbance* of a technology mix that is virtually co-located at the LT end of the testloop. This noise is represented by equivalent disturbance generator G1, when stressing upstream signals, and by equivalent disturbance generator G2 when stressing downstream signals.
- The profiles X.NT.# in this section describe the total *equivalent disturbance* of a technology mix that is virtually co-located at the NT end of the testloop. This noise is represented by equivalent disturbance generator G2, when stressing upstream signals, and by equivalent disturbance generator G1 when stressing downstream signals.

This naming convention use "XS" for equivalent self disturbers, "XA" for equivalant alien disturbers, "X" for the overall equivalent disturbers, "#" to identify the involved noise model and "♦" as the weighed crosstalk sum of self and alien noise.
Mark that the PSD levels of equivalent disturbance generator G1 and G2 are interchanged when changing upstream testing into downstream testing.

6.4.1. Frequency domain profiles for SDSL testing

This sub-clause specifies the PSD profiles (XS.LT.#), (XA.LT.#), (XS.NT.#) and (XA.NT.#) that apply for the equivalent disturbers G1 and G2 when testing SDSL systems (see figure 9, clause 6.3.1 and clause 6.3.2.). In this nomenclature is "#" used as a placeholder for noise model "A", "B" ,"C", and "D".

Four noise models have been defined for SDSL

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

- **Type "B" models** are intended to represent a ***medium penetration scenario*** where the SDSL system under test is placed in a distribution cable (up to tens of wire pairs) that is filled with many other (potentially incompatible) transmission systems.
- **Type "C" models** are intended to represent a ***legacy scenario*** that accounts for systems such as ISDN-PRI (HDB3), in addition to the medium penetration scenario of model "B".
- **Type "D" models** are intended as ***pure self-crosstalk scenario*** to demonstrate the difference between a cable filled with SDSL only, or filled with a mixture of xDSL techniques.

The overall crosstalk noise of equivalent disturbers G1 and G2 (see figure 9) is specified in an indirect way by means of a self and an alien crosstalk noise profile. These two parts shall be combined as specified in clause 6.3.1 and 6.3.2.
These profiles shall be met for all frequencies between 1 kHz to 1 MHz.

6.4.1.1. Self crosstalk profiles for SDSL

The noise profiles (XS.LT.#) and (XS.NT.#), representing the equivalent disturbance of self crosstalk, are implementation specific of the SDSL system under test. Transceiver manufacturers are left to determine these levels. For compliance with the requirements of this technical specification, the transceiver manufacturer shall determine the signal spectrum of the SDSL system under test, as it can be observed at the Tx port of the test set-up as described in sub clause 4.1. The measurement bandwidth for PSD shall be 1 kHz or less.

For testing SDSL, four noise models for self crosstalk have been defined. The LT- and NT-profiles are specified in table 4.
In this nomenclature is "#" a placeholder for model "A", "B" ,"C" or "D". "SDSL.dn" is the signal spectrum that SDSL transmits in downstream direction, and "SDSL.up" in upstream direction.

	Model A (XS.#.A)	**Model B** (XS.#.B)	**Model C** (XS.#.C)	**Model D** (XS.#.D)
XS.LT.#:	"SDSL.dn" + 11.7 dB	"SDSL.dn" + 7.1 dB	"SDSL.dn" + 7.1 dB	"SDSL.dn" + 10.1 dB
XS.NT.#:	"SDSL.up" + 11.7 dB	"SDSL.up" + 7.1 dB	"SDSL.up" + 7.1 dB	"SDSL.up" + 10.1 dB

Table 4: Definition of the self crosstalk for SDSL testing. The different noise models use different Gain factors.

6.4.1.2. Alien crosstalk profiles for SDSL

The noise profiles (XA.LT.#) and (XA.NT.#), representing the equivalent disturbance of alien crosstalk, are implementation specific of the SDSL system under test. For testing SDSL, four noise models for alien crosstalk have been defined, The LT-profiles are specified in table 5 and the NT-profiles in table 6. Each PSD profile originates from a mix of disturbers, as described in annex B. The alien noise in model D is made inactive, to achieve one pure self crosstalk scenario.

XA.LT.A [Hz]	***135 Ω*** **[dBm/Hz]**
1	-20.0
15 k	-20.0
30 k	-21.5
67 k	-27.0
125 k	-27.0
138 k	-25.7
400 k	-26.1
1104 k	-26.1
2.5 M	-66.2
4.55 M	-96.5
30 M	-96.5

XA.LT.B [Hz]	***135 Ω*** **[dBm/Hz]**
1	-25.7
15 k	-25.7
30 k	-27.4
45 k	-30.3
70 k	-36.3
127 k	-36.3
138 k	-32.1
400 k	-32.5
550 k	-32.5
610 k	-34.8
700 k	-35.4
1104 k	-35.4
4.55 M	-103.0
30 M	-103.0

XA.LT.C [Hz]	***135 Ω*** **[dBm/Hz]**
1	-25.7
15 k	-25.7
30 k	-27.4
45 k	-30.3
70 k	-36.3
127 k	-36.3
138 k	-32.1
400 k	-32.5
550 k	-32.5
610 k	-34.8
700 k	-35.3
1104 k	-35.3
1.85 M	-58.5
22.4 M	-103.0
30 M	-103.0

XA.LT.D [Hz]	***135 Ω*** **[dBm/Hz]**
ALL	*ZERO*

Table 5: Break frequencies of the "XA.LT.#" PSD profiles that specify the equivalent disturbance spectra of alien disturbers for testing SDSL systems. The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale. The levels are defined with into a 135Ω resistive load.

XA.NT.A [Hz]	***135 Ω*** **[dBm/Hz]**
1	-20.0
15 k	-20.0
60 k	-25.2
276 k	-25.8
500 k	-51.9
570 k	-69.5
600 k	-69.9
650 k	-62.4
763 k	-62.4
1.0 M	-71.5
2.75 M	-96.5
30 M	-96.5

XA.NT.B [Hz]	***135 Ω*** **[dBm/Hz]**
1	-25.7
15 k	-25.7
30 k	-26.8
67 k	-31.2
142 k	-31.2
156 k	-32.7
276 k	-33.2
400 k	-46.0
500 k	-57.9
570 k	-75.7
600 k	-76.0
650 k	-68.3
763 k	-68.3
1.0 M	-77.5
2.8 M	-103.0
30 M	-103.0

XA.NT.C [Hz]	***135 Ω*** **[dBm/Hz]**
1	-25.7
15 k	-25.7
30 k	-26.8
67 k	-31.2
142 k	-31.2
156 k	-32.7
276 k	-33.2
335 k	-42.0
450 k	-47.9
750 k	-45.4
1040 k	-45.5
2.46 M	-63.6
23.44 M	-103.0
30 M	-103.0

XA.NT.D [Hz]	***135 Ω*** **[dBm/Hz]**
ALL	*ZERO*

Table 6: Break frequencies of the "XA.NT.#" PSD profiles that specify the equivalent disturbance specta of alien disturbers for testing SDSL systems. The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale. The levels are defined with into a 135Ω resistive load.

6.4.2. Frequency domain profiles for ADSL over POTS testing

This sub-clause specifies 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 systems. In this nomenclature is “#” used as a placeholder for noise model “A”, “B” ,”C”, and "D".

Four noise models have been defined for ADSL over POTS.

- **Type “A” models** are intended to represent a ***high penetration scenario*** where the ADSL system under test is placed in a distribution cable (up to hundreds of wire pairs) that is filled with many other (potentially incompatible) transmission systems.
- **Type “B” models** are intended to represent a ***medium penetration scenario*** where the ADSL system under test is placed in a distribution cable (up to tens of wire pairs) that is filled with many other (potentially incompatible) transmission systems.
- **Type “C” models** are intended to represent a ***legacy scenario*** that accounts for systems such as ISDN-PRI (HDB3), in addition to the medium penetration scenario of model “B”.
- **Type “D” models** are intended as ***pure self-crosstalk scenario*** to demonstrate the difference between a cable filled with ADSL over POTS only, or filled with a mixture of xDSL techniques.

The overall crosstalk noise of equivalent disturbers G1 and G2 (see figure 9) is specified in a direct way by means of an overall noise profile. The LT-profiles are specified in table 7 and the NT-profiles in table 8. Each PSD profile originates from a mix of disturbers, as described in annex B.
These profiles shall be met for all frequencies between 1 kHz to 2 MHz.

X.LT.A [Hz]	***135 Ω* [dBm/Hz]**
0	-20.0
15 k	-20.0
31 k	-21.5
63 k	-25.6
112 k	-25.7
204 k	-26.1
298 k	-26.6
420 k	-27.3
1.104 M	-27.3
4.5 M	-97.8
30 M	-97.8

X.LT.B [Hz]	***135 Ω* [dBm/Hz]**
0	-25.6
15 k	-25.6
31 k	-27.0
63 k	-31.3
112 k	-31.3
204 k	-31.8
298 k	-32.5
420 k	-33.7
1.104 M	-33.7
4.5 M	-104.1
30 M	-104.1

X.LT.C [Hz]	***135 Ω* [dBm/Hz]**
0	-25.6
15 k	-25.6
31 k	-27.0
63 k	-31.3
112 k	-31.3
204 k	-31.8
298 k	-32.5
420 k	-33.7
1.104 M	-33.7
1.85 M	-58.1
23 M	-104.1
30 M	-104.1

X.LT.D [Hz]	***135 Ω* [dBm/Hz]**
0.0	-87.4
3.99 k	-87.4
4 k	-82.4
25.875k	-29.4
1.104 M	-29.4
3.093 M	-79.9
4.545 M	-99.9
30 M	-99.9

Table 7: Break frequencies of the “X.LT.#” PSD masks that specify the equivalent disturbance for testing ADSL over POTS systems. The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale. The levels are defined with into a 135Ω resistive load.

X.NT.A [Hz]	*135 Ω* [dBm/Hz]
0	-20.0
15 k	-20.0
22 k	-20.8
29 k	-20.8
61 k	-24.4
138 k	-24.5
153 k	-28.2
220 k	-28.9
315 k	-30.8
387 k	-34.6
461 k	-43.4
595 k	-62.5
755 k	-62.5
1.2 M	-75.3
2.6 M	-97.8
30 M	-97.8

X.NT.B [Hz]	*135 Ω* [dBm/Hz]
0	-25.6
15 k	-25.6
22 k	-26.6
29 k	-26.6
61 k	-30.3
138 k	-30.4
153 k	-33.2
220 k	-33.9
315 k	-35.5
387 k	-39.5
461 k	-48.3
605 k	-68.4
755 k	-68.4
1.2 M	-82.0
2.9 M	-104.1
30 M	-104.1

X.NT.C [Hz]	*135 Ω* [dBm/Hz]
0	-25.6
15 k	-25.6
22 k	-26.6
29 k	-26.6
61 k	-30.3
138 k	-30.4
153 k	-33.2
220 k	-33.9
315 k	-35.5
387 k	-39.5
469 k	-48.0
776 k	-45.5
1030 k	-45.5
1.41 M	-48.9
1.8 M	-57.9
23 M	-104.1
30 M	-104.1

X.NT.D [Hz]	*135 Ω* [dBm/Hz]
0	-87.4
3.99 k	-87.4
4 k	-82.4
25.875 k	-27.4
138 k	-27.4
307 k	-79.9
1.221 M	-79.9
1.63 M	-99.9
30 M	-99.9

Table 8: Break frequencies of the "X.NT.#" PSD masks that specify the equivalent disturbance for testing ADSL over POTS systems. The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale. The levels are defined with into a 135Ω resistive load.

6.4.3. Frequency domain profiles for ADSL over ISDN testing

This sub-clause specifies the PSD profiles (X.LT.#) and (X.NT.#) that apply for the equivalent disturbers G1 and G2 (see figure 9) when testing ADSL over ISDN systems. In this nomenclature is "#" used as a placeholder for noise model "A", "B" ,"C", and "D".

Four noise models have been defined for ADSL over ISDN:

- **Type "A" models** are intended to represent a ***high penetration scenario*** where the ADSL system under test is placed in a distribution cable (up to hundreds of wire pairs) that is filled with many other (potentially incompatible) transmission systems.
- **Type "B" models** are intended to represent a ***medium penetration scenario*** where the ADSL system under test is placed in a distribution cable (up to tens of wire pairs) that is filled with many other (potentially incompatible) transmission systems.
- **Type "C" models** are intended to represent a ***legacy scenario*** that accounts for systems such as ISDN-PRI (HDB3), in addition to the medium penetration scenario of model "B".
- **Type "D" models** are intended as ***pure self-crosstalk scenario*** to demonstrate the difference between a cable filled with ADSL over POTS only, or filled with a mixture of xDSL techniques.

The LT-profiles are specified in table 9 and the NT-profiles in table 10. Each PSD profile originates from a mix of disturbers, as described in annex B.
These profiles shall be met for all frequencies between 1 kHz to 2 MHz.

X.LT.A [Hz]	***135 Ω*** **[dBm/Hz]**
0	-20.0
15 k	-20.0
30 k	-21.5
66 k	-27.7
130 k	-27.7
138 k	-25.9
204 k	-26.1
298 k	-26.6
420 k	-27.3
1.104 M	-27.3
4.5 M	-97.8
30	-97.8

X.LT.B [Hz]	***135 Ω*** **[dBm/Hz]**
0	-25.6
15 k	-25.6
30 k	-27.2
66 k	-32.6
130 k	-32.7
138 k	-31.5
204 k	-31.8
298 k	-32.5
420 k	-33.7
1.104 M	-33.7
4.5 M	-104.1
30 M	-104.1

X.LT.C [Hz]	***135 Ω*** **[dBm/Hz]**
0	-25.6
15 k	-25.6
30 k	-27.2
66 k	-32.6
130 k	-32.7
138 k	-31.5
204 k	-31.8
298 k	-32.5
420 k	-33.7
1.104 M	-33.7
1.85 M	-58.1
23 M	-104.1
30 M	-104.1

X.LT.D [Hz]	***135 Ω*** **[dBm/Hz]**
0	-79.9
50 k	-79.9
80 k	-71.8
138 k	-29.4
1.104 M	-29.4
3.093 M	-79.9
4.545 M	-99.9
30 M	-99.9

Table 9: Break frequencies of the "X.LT.#" PSD masks that specify the equivalent disturbance for testing ADSL over ISDN systems. The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a *<u>logarithmic</u>* frequency scale and a *<u>linear</u>* dBm scale. The levels are defined with into a 135Ω resistive load.

X.NT.A [Hz]	***135 Ω*** **[dBm/Hz]**
0	-20.0
15 k	-20.0
30 k	-21.6
66 k	-27.7
129 k	-27.7
138 k	-24.5
276 k	-24.9
298 k	-28.8
387 k	-34.6
500 k	-48.6
595 k	-62.5
755 k	-62.5
1.2 M	-75.3
2.6 M	-97.8
30 M	-97.8

X.NT.B [Hz]	***135 Ω*** **[dBm/Hz]**
0	-25.6
15 k	-25.6
30 k	-27.1
65 k	-32.6
129 k	-32.7
138 k	-30.4
276 k	-31.0
296 k	-34.1
381 k	-38.8
461 k	-48.3
605 k	-68.4
755 k	-68.4
1.2 M	-82.0
2.9 M	-104.1
30 M	-104.1

X.NT.C [Hz]	***135 Ω*** **[dBm/Hz]**
0	-25.6
15 k	-25.6
30 k	-27.1
65 k	-32.6
129 k	-32.7
138 k	-30.4
276 k	-31.0
296 k	-34.1
381 k	-38.8
469 k	-48.0
776 k	-45.5
1.030 M	-45.5
1.410 M	-48.9
1.8 M	-57.9
23 M	-104.1
30 M	-104.1

X.NT.D [Hz]	***135 Ω*** **[dBm/Hz]**
0	-79.9
50 k	-79.9
80 k	-71.8
138 k	-27.4
276 k	-27.4
614 k	-79.9
1.221 M	-79.9
1.63 M	-99.9
30 M	-99.9

Table 10: Break frequencies of the "X.NT.#" PSD masks that specify the equivalent disturbance for testing ADSL over ISDN systems. The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a *<u>logarithmic</u>* frequency scale and a *<u>linear</u>* dBm scale. The levels are defined with into a 135Ω resistive load.

6.4.4. Time domain profiles of generator G1-G4 for all xDSL tests

The noise, as specified in the frequency domain in sub-clause 6.3.1 to 6.3.4, 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 1) shall lie between the two boundaries as illustrated in figure 10 and defined in table 11.

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 upto 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 characterised by peak values that are occasionally significantly higher than the rms-value of that noise (up to 5 times the rms-value).

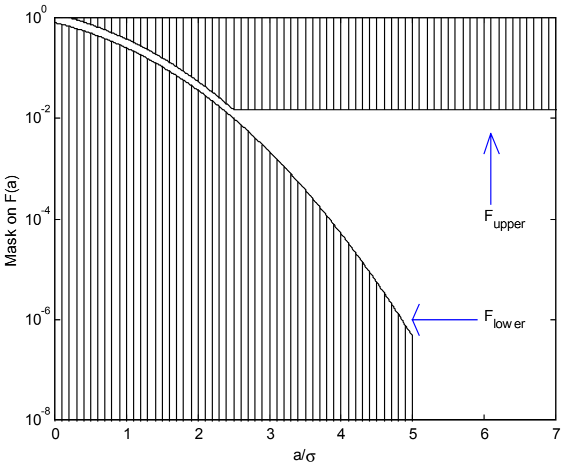


Figure 10: Mask for the Amplitude Distribution Function: the non-shaded area is the allowed region. The boundaries of the mask are specified in Table 11.

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

Table 11: Upper and lower boundaries of the amplitude distribution function of the noise.

The meaning of the parameters in table 11 is as follows:

- CF denotes the minimum crest factor of the noise, that characterises the ratio between the absolute peak value and rms value ($CF = |u_{peak}| / u_{rms}$).
- ε denotes the gaussian gap that indicates how ‘close’ 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 practible repetition length.

6.5. Example of the generated impairment (informative)

Figure 11 illustrates this for the ***alien*** noise (other then the xDSL modem under test) in the case that the length of testloop #1 is fixed at 3 km. Figure 12 illustrates this for various loop lengths in the case that the ***alien*** noise of model ‘B’ is applied. These figures are restricted to alien noise only, because the PSD of SDSL is for further study. The self noise (of SDSL) shall be combined with this alien noise.

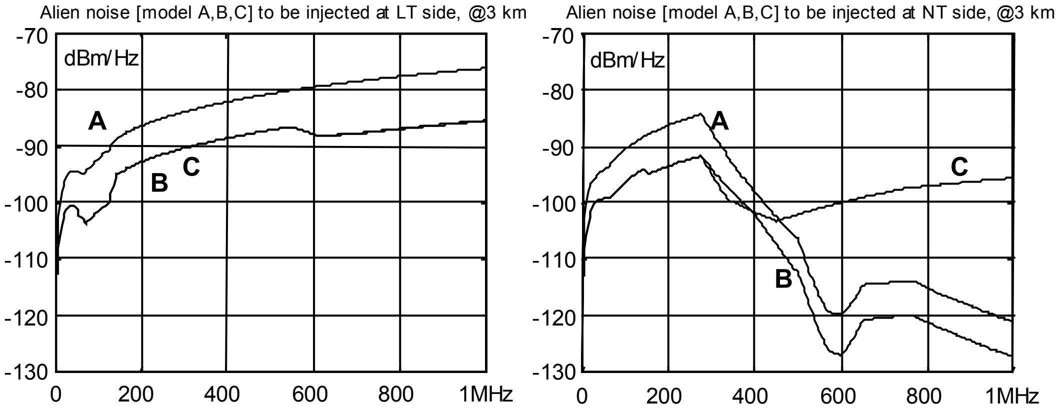


Figure 11: Examples of alien noise spectra that are to be injected into the test setup, while testing SDSL systems. This is the noise, resulting from three of the four noise models for SDSL, in the case that the length of testloop #2 is fixed at 3 km.

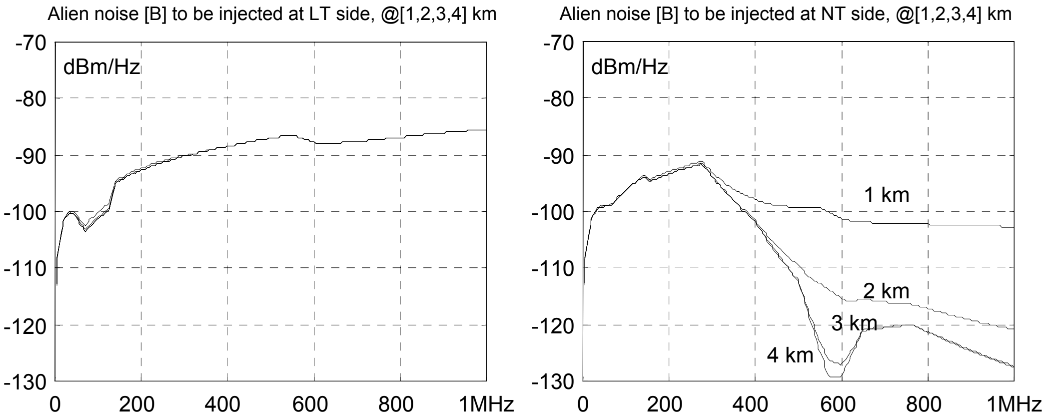


Figure 12: Examples of alien noise spectra that are to be injected into the test setup, while testing SDSL systems. This is the alien noise, resulting from noise model B for SDSL, in the case that the length of testloop #2 varies from 1 km to 4 km. This demonstrates that the test noise is length dependent, to represent the FEXT in real access network cables.

7. Performance Objectives

This clause specifies what loop length an xDSL modem under test shall reach with at least 6 dB noise margin, at given payload bitrate, noise model and testloop. To minimise the electrical differences between different testloop configurations, the “length” of a loop is specified as “electrical length” instead of the “physical length” of all cascaded sections (meaningful only when real cables are used). The electrical length is equivalent to the insertion loss of the loop at specified test frequency and termination.
The relation between electrical length (insertion loss) and total physical length (when real cables are used) can be calculated from the two-port cable models.

7.1. Performance objectives for SDSL

The length of each test loop for SDSL modems is specified in table 12 and 13. The specified insertion loss Y at the specified test frequency measured with a 135Ω termination (*electrical* length) is mandatory. If implementation tolerances of one testloop causes that its resulting *electrical* length is out of specification, then its total *physical* length shall be scaled accordingly to adjust this error.

The test frequency f_T is chosen to be a typical mid-band frequency in the spectrum SDSL systems. The length is chosen to be a typical maximum value that can be handled correctly by the SDSL transceiver under test. This value is bitrate dependent; the higher the payload bit-rate, the lower the insertion loss is that can be handled in practice.

SDSL, Noise model A

Payload Bitrate [kb/s]		**f_T [kHz]**	**Y [dB] @f_T, @135Ω**	L1 [m]	L2 [m]	L3 [m]	L4 [m]	L5 [m]	L7 [m]		**f_T [kHz]**	**Y [dB] @f_T, @135Ω**	L6 [m]
384		**150**	**43.0**	< 3	4106	5563	5568	11064	4698		**115**	**40.5**	3165
512		**150**	**37.0**	< 3	3535	4787	4789	9387	3996		**115**	**35.0**	2646
768		**150**	**29.0**	< 3	2773	3747	3753	7153	3062		**275**	**34.5**	1904
1024		**150**	**25.5**	< 3	2439	3285	3291	6174	2668		**275**	**30.0**	1547
1280		**150**	**22.0**	< 3	2105	2829	2837	5193	2266		**275**	**26.0**	1284
1536		**150**	**19.0**	< 3	1820	2453	2455	4357	1900		**250**	**21.5**	1052
2048 (s)		**200**	**17.5**	< 3	1558	2046	2052	3285	1550		**250**	**18.5**	748
2304 (s)		**200**	**15.5**	< 3	1381	1815	1820	2789	1331		**250**	**16.5**	583
2048 (a)		**250**	**21.0**	< 3	1743	2264	2272	3618	1726		**250**	**21.0**	1001
2304 (a)		**250**	**18.0**	< 3	1494	1927	1937	2915	1402		**250**	**18.0**	702

Table 12: Performance objectives for SDSL when tested at SDSL noise model A over various testloops. The electrical length Y (insertion loss at specified frequency f_T) is mandatory, the (estimated) physical lengths L1-L7 are informative.
(s) those electrical lengths apply to the symmetric PSD
(a) those electrical lengths apply to the asymmetric PSD

SDSL, Noise model B, C, D

Payload Bitrate [kb/s]		**f_T [kHz]**	**Y [dB] @f_T, @135Ω**	L1 [m]	L2 [m]	L3 [m]	L4 [m]	L5 [m]	L7 [m]		**f_T [kHz]**	**Y [dB] @f_T, @135Ω**	L6 [m]
384		**150**	**50.0**	< 3	4773	6471	6477	13021	5508		**115**	**47.5**	3859
512		**150**	**44.0**	< 3	4202	5692	5698	11344	4814		**115**	**41.5**	3261
768		**150**	**35.5**	< 3	3392	4592	4596	8970	3815		**275**	**42.0**	2536
1024		**150**	**32.0**	< 3	3058	4135	4141	7990	3403		**275**	**38.0**	2223
1280		**150**	**28.5**	< 3	2725	3678	3684	7011	3006		**275**	**33.5**	1816
1536		**150**	**25.5**	< 3	2439	3285	3291	6174	2673		**250**	**29.0**	1680
2048 (s)		**200**	**24.0**	< 3	2135	2812	2820	4886	2271		**250**	**25.5**	1426
2304 (s)		**200**	**21.5**	< 3	1913	2509	2518	4257	2010		**250**	**23.0**	1208
2048 (a)		**250**	**28.0**	< 3	2323	3030	3034	5189	2389		**250**	**28.0**	1607
2304 (a)		**250**	**25.0**	< 3	2075	2699	2705	4514	2102		**250**	**25.0**	1387

Table 13: Performance objectives for SDSL when tested at SDSL noise model B, C or D over various testloops. The electrical length Y (insertion loss at specified frequency f_T) is mandatory, the (estimated) physical lengths L1-L7 are informative.
(s) those electrical lengths apply to the symmetric PSD
(a) those electrical lengths apply to the asymmetric PSD

ED NOTE The informative physical lengths are evaluated, using a "cubic spline interpolation" from the RLC-parameters summarized in TD18 (Helsinki), that are 100% identical to the parameters that were extended to 2 MHz in TD23 (Edinburgh)

7.2. Performance objectives for ADSL over POTS

The length of each test loop for ADSL over POTS modems is specified in table [*] to [*]. The specified insertion loss Y at the specified test frequency measured with a 135Ω termination (*electrical* length) is mandatory. The predicted physical length is calculated from this electricvl lengt, and is informative. If implementation tolerances of one testloop causes that its resulting *electrical* length is out of specification, then its total *physical* length shall be scaled accordingly to adjust this error.

The test frequency f_T is chosen to be a typical mid-band frequency in the spectrum ADSL over POTS systems. The electrical length is chosen to be a typical maximum value that can be handled correctly by the ADSL over POTS transceiver under test. This value is bitrate dependent; the higher the payload bit-rate, the lower the insertion loss is that can be handled in practice.

The performance objectives are to be measured in upstream and downstream, while simultaneously the transceiver is maximizing the bitrate in the opposite direction. This should be checked by measuring the PSD of the transmitter which should be around –40 dBm/Hz (in downstream) or –38 dBm/Hz (in upstream) in the passband of the tranceiver. (In downstream on longer lines the highest used carrier frequencies could be below 255).

ED NOTE These performance objectives are still under study within the ADSL project

Noise model A

Payload Bitrate [kb/s]		**f_T [kHz]**	**Y [dB] @f_T, @135Ω**	L0 [m]	L1 [m]	L2 [m]	L3 [m]	L4 [m]	L5 [m]	L6 [m]	L7 [m]		**f_T [kHz]**	**Y [dB] @f_T, @135Ω**	L8 [m]
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											

Noise model B, C, D

Payload Bitrate [kb/s]		**f_T [kHz]**	**Y [dB] @f_T, @135Ω**	L0 [m]	L1 [m]	L2 [m]	L3 [m]	L4 [m]	L5 [m]	L6 [m]	L7 [m]		**f_T [kHz]**	**Y [dB] @f_T, @135Ω**	L8 [m]
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											
				< 3											

Table 14: Performance objectives for upstream ADSL over POTS when tested at various ADSL over POTS noise models over various testloops. The electrical length Y (insertion loss at specified frequency f_T) is mandatory, the (estimated) physical lengths L1-L8 are informative.

7.3. Performance objectives for ADSL over ISDN

The length of each test loop for ADSL over ISDN modems is specified in table [*] to [*]. The specified insertion loss Y at the specified test frequency measured with a 135Ω termination (*electrical* length) is mandatory. The predicted physical length is calculated from this electricvl lengt, and is informative. If implementation tolerances of one testloop causes that its resulting *electrical* length is out of specification, then its total *physical* length shall be scaled accordingly to adjust this error.

The test frequency f_T is chosen to be a typical mid-band frequency in the spectrum ADSL over ISDN systems. The electrical length is chosen to be a typical maximum value that can be handled correctly by the ADSL over ISDN transceiver under test. This value is bitrate dependent; the higher the payload bit-rate, the lower the insertion loss is that can be handled in practice.

The performance objectives are to be measured in upstream and downstream, while simultaneously the transceiver is maximizing the bitrate in the opposite direction. This should be checked by measuring the PSD of the transmitter which should be around –40 dBm/Hz (in downstream) or –38 dBm/Hz (in upstream) in the passband of the tranceiver. (In downstream on longer lines the highest used carrier frequencies could be below 255).

7.3.1 Downstream performance for ADSL over ISDN

ADSL over ISDN, Downstream, Noise model A, Loop 1-4

Payload Bitrate [kb/s]	**f_T [kHz]**	L1 [m]	**L1 Y [dB] @f_T, @135Ω**	L2 [m]	**L2 Y [dB] @f_T, @135Ω**	L3 [m]	**L3 Y [dB] @f_T, @135Ω**	L4 [m]	**L4 Y [dB] @f_T, @135Ω**
512	**300**	2800	**40.0**	3590	**38.5**	3120	**39.0**	3260	**38.5**
768	**300**	2730	**39.0**	3470	**37.0**	3050	**38.0**	3170	**37.5**
1024	**300**	2670	**38.0**	3380	**36.0**	3000	**37.5**	3130	**37.0**
1544	**300**	2590	**37.0**	3290	**35.0**	2910	**36.0**	3050	**36.0**
2048	**300**	2510	**36.0**	3210	**34.0**	2840	**35.0**	2960	**34.5**
3072	**300**	2280	**32.5**	2940	**31.5**	2610	**32.0**	2750	**31.5**
4096	**300**	2080	**29.5**	2670	**28.5**	2410	**29.0**	2540	**28.5**
5120	**300**	1800	**25.5**	2270	**24.0**	2100	**25.0**	2240	**24.5**
6144	**300**	1400	**20.0**	1710	**18.0**	1670	**18.5**	-	**-**

ADSL over ISDN, Downstream, Noise model A, Loop 5-8

Payload Bitrate [kb/s]	**f_T [kHz]**	L5 [m]	**L5 Y [dB] @f_T, @135Ω**	L6 [m]	**L6 Y [dB] @f_T, @135Ω**	L7 [m]	**L7 Y [dB] @f_T, @135Ω**	L8 [m]	**L8 Y [dB] @f_T, @135Ω**
512	**300**	3410	**39.0**	3250	**39.0**	4920	**38.0**	2430	**44.0**
768	**300**	3350	**38.0**	3170	**38.0**	4820	**36.5**	2390	**43.5**
1024	**300**	3300	**37.5**	3120	**37.0**	4760	**36.0**	2350	**43.0**
1544	**300**	3200	**36.0**	3040	**36.0**	4690	**35.0**	2260	**41.5**
2048	**300**	3100	**34.5**	2940	**34.5**	4610	**34.0**	2140	**40.0**
3072	**300**	2900	**31.5**	2740	**31.5**	4410	**31.0**	1910	**36.5**
4096	**300**	2680	**28.5**	2540	**29.0**	-	**-**	1690	**33.5**
5120	**300**	2370	**24.0**	2220	**24.5**	-	**-**	1400	**29.5**
6144	**300**	1890	**17.5**	1770	**18.0**	-	**-**	-	

ADSL over ISDN, Downstream, Noise model B, Loop 1-4

Payload Bitrate [kb/s]	**f_T [kHz]**	L1 [m]	**L1 Y [dB] @f_T, @135Ω**	L2 [m]	**L2 Y [dB] @f_T, @135Ω**	L3 [m]	**L3 Y [dB] @f_T, @135Ω**	L4 [m]	**L4 Y [dB] @f_T, @135Ω**
512	**300**	3090	**44.0**	4000	**43.0**	3430	**43.5**	3570	**43.0**
768	**300**	3020	**43.0**	3870	**41.5**	3330	**42.0**	3500	**42.0**
1024	**300**	2950	**42.0**	3790	**40.0**	3270	**41.0**	3420	**41.0**
1544	**300**	2870	**41.0**	3680	**39.5**	3190	**40.0**	3330	**40.0**
2048	**300**	2790	**40.0**	3580	**38.0**	3120	**39.0**	3250	**39.0**
3072	**300**	2610	**37.0**	3370	**36.0**	2940	**37.0**	3100	**36.5**
4096	**300**	2440	**35.0**	3170	**34.0**	2800	**34.5**	2930	**34.0**
5120	**300**	2270	**32.5**	2910	**31.0**	2600	**32.0**	2740	**31.5**
6144	**300**	2040	**29.0**	2610	**28.0**	2360	**28.5**	2500	**28.0**

ADSL over ISDN, Downstream, Noise model B, Loop 5-8

Payload Bitrate [kb/s]	**f_T [kHz]**	L5 [m]	**L5 Y [dB] @f_T, @135Ω**	L6 [m]	**L6 Y [dB] @f_T, @135Ω**	L7 [m]	**L7 Y [dB] @f_T, @135Ω**	L8 [m]	**L8 Y [dB] @f_T, @135Ω**
512	**300**	3730	**43.5**	3560	**43.5**	5250	**43.0**	2690	**48.0**
768	**300**	3630	**42.0**	3470	**42.0**	5140	**41.0**	2650	**47.0**
1024	**300**	3590	**41.5**	3390	**41.0**	5070	**40.0**	2610	**46.5**
1544	**300**	3500	**40.0**	3320	**40.0**	4990	**39.0**	2540	**45.5**
2048	**300**	3410	**39.0**	3250	**39.0**	4920	**38.0**	2450	**44.5**
3072	**300**	3230	**36.5**	3070	**36.5**	4760	**36.0**	2240	**41.5**
4096	**300**	3070	**34.0**	2910	**34.0**	4600	**33.5**	2070	**39.0**
5120	**300**	2890	**31.5**	2720	**31.5**	4380	**30.5**	1870	**36.0**
6144	**300**	2640	**28.0**	2490	**28.0**	-	**-**	1650	**33.0**

ADSL over ISDN, Downstream, Noise model C, Loop 1-4

Payload Bitrate [kb/s]	**f$_T$ [kHz]**	L1 [m]	**L1 Y [dB] @f$_T$, @135Ω**	L2 [m]	**L2 Y [dB] @f$_T$, @135Ω**	L3 [m]	**L3 Y [dB] @f$_T$, @135Ω**	L4 [m]	**L4 Y [dB] @f$_T$, @135Ω**
512	**300**	2560	**36.5**	3370	**36.0**	2910	**36.0**	3110	**36.5**
768	**300**	2480	**35.5**	3290	**35.0**	2860	**35.5**	3030	**35.5**
1024	**300**	2410	**34.5**	3200	**34.0**	2790	**34.5**	2950	**34.5**
1544	**300**	2240	**32.0**	2940	**31.5**	2600	**31.5**	2750	**31.5**
2048	**300**	2080	**29.5**	2710	**29.0**	2430	**29.5**	2580	**29.0**
3072	**300**	1820	**26.0**	2360	**25.0**	2160	**25.5**	2300	**25.0**
4096	**300**	1630	**23.0**	2100	**22.0**	1960	**22.5**	-	**-**
5120	**300**	1470	**21.0**	1890	**20.0**	1810	**20.5**	-	**-**
6144	**300**	1300	**18.5**	1660	**18.0**	1630	**18.0**	-	**-**

ADSL over ISDN, Downstream, Noise model C, Loop 5-8

Payload Bitrate [kb/s]	**f$_T$ [kHz]**	L5 [m]	**L5 Y [dB] @f$_T$, @135Ω**	L6 [m]	**L6 Y [dB] @f$_T$, @135Ω**	L7 [m]	**L7 Y [dB] @f$_T$, @135Ω**	L8 [m]	**L8 Y [dB] @f$_T$, @135Ω**
512	**300**	3220	**36.0**	3050	**36.0**	4770	**36.0**	2120	**39.5**
768	**300**	3130	**35.0**	2970	**35.0**	4710	**35.0**	2050	**38.5**
1024	**300**	3060	**34.0**	2900	**34.0**	4650	**34.0**	1960	**37.5**
1544	**300**	2890	**31.5**	2730	**31.5**	4440	**31.0**	1780	**35.0**
2048	**300**	2730	**29.0**	2560	**29.0**	4260	**29.0**	1640	**33.0**
3072	**300**	2450	**25.5**	2290	**25.5**	-	**-**	1420	**30.0**
4096	**300**	2250	**22.5**	2090	**22.5**	-	**-**	1260	**27.0**
5120	**300**	2080	**20.0**	1930	**20.0**	-	**-**	-	**-**
6144	**300**	1910	**17.5**	1750	**17.5**	-	**-**	-	**-**

ADSL over ISDN, Downstream, Noise model D Loop 1-4

Payload Bitrate [kb/s]	**f$_T$ [kHz]**	L1 [m]	**L1 Y [dB] @f$_T$, @135Ω**	L2 [m]	**L2 Y [dB] @f$_T$, @135Ω**	L3 [m]	**L3 Y [dB] @f$_T$, @135Ω**	L4 [m]	**L4 Y [dB] @f$_T$, @135Ω**
512	**300**	3740	**53.0**	4770	**51.0**	4060	**52.5**	4200	**52.0**
768	**300**	3620	**51.5**	4620	**49.5**	3940	**51.0**	4080	**50.5**
1024	**300**	3520	**50.0**	4490	**48.0**	3840	**49.5**	3980	**49.0**
1544	**300**	3340	**47.5**	4270	**45.5**	3670	**47.0**	3810	**46.5**
2048	**300**	3200	**45.5**	4090	**43.5**	3520	**45.0**	3650	**44.5**
3072	**300**	2950	**42.0**	3780	**40.5**	3270	**41.5**	3410	**41.0**
4096	**300**	2740	**39.0**	3510	**37.5**	3070	**38.5**	3210	**38.0**
5120	**300**	2480	**35.5**	3180	**34.0**	2810	**34.5**	2940	**34.5**
6144	**300**	2160	**31.0**	2740	**29.0**	2470	**30.0**	2610	**29.5**

ADSL over ISDN, Downstream, Noise model D Loop 5-8

Payload Bitrate [kb/s]	**f$_T$ [kHz]**	L5 [m]	**L5 Y [dB] @f$_T$, @135Ω**	L6 [m]	**L6 Y [dB] @f$_T$, @135Ω**	L7 [m]	**L7 Y [dB] @f$_T$, @135Ω**	L8 [m]	**L8 Y [dB] @f$_T$, @135Ω**
512	**300**	4350	**52.0**	4190	**52.5**	5850	**51.0**	3360	**57.5**
768	**300**	4230	**50.5**	4070	**51.0**	5730	**49.5**	3200	**55.0**
1024	**300**	4130	**49.0**	3970	**49.5**	5630	**48.0**	3120	**54.0**
1544	**300**	3950	**46.5**	3790	**46.5**	5450	**45.5**	2970	**52.0**
2048	**300**	3810	**44.5**	3650	**44.5**	5310	**43.5**	2830	**50.0**
3072	**300**	3560	**41.0**	3400	**41.0**	5060	**40.0**	2610	**46.5**
4096	**300**	3340	**38.0**	3190	**38.0**	4840	**37.0**	2390	**43.5**
5120	**300**	3080	**34.0**	2930	**34.5**	4550	**33.5**	2130	**40.0**
6144	**300**	2730	**29.0**	2590	**29.5**	-	**-**	1790	**35.0**

7.3.2 Upstream performance for ADSL over ISDN

ADSL over ISDN, Upstream, Noise model A Loop 1-4

Payload Bitrate [kb/s]	f_T [kHz]	L1 [m]	L1 Y [dB] @f_T, @135Ω	L2 [m]	L2 Y [dB] @f_T, @135Ω	L3 [m]	L3 Y [dB] @f_T, @135Ω	L4 [m]	L4 Y [dB] @f_T, @135Ω
64	300	2620	37.5	3760	40.0	3070	38.5	3270	39.0
128	300	2480	35.5	3520	37.5	2920	36.0	3110	37.0
256	300	2280	32.5	3170	34.0	2700	33.0	2890	33.5
384	300	2120	30.0	2930	31.0	2520	30.5	2710	31.0
512	300	1910	27.5	2560	27.5	2340	28.0	2510	28.0
640	300	1680	24.0	2330	25.0	2100	24.5	2280	25.0

ADSL over ISDN, Upstream, Noise model A Loop 5-8

Payload Bitrate [kb/s]	f_T [kHz]	L5 [m]	L5 Y [dB] @f_T, @135Ω	L6 [m]	L6 Y [dB] @f_T, @135Ω	L7 [m]	L7 Y [dB] @f_T, @135Ω	L8 [m]	L8 Y [dB] @f_T, @135Ω
64	300	3400	39.0	3240	39.0	5110	41.0	2190	40.5
128	300	3250	36.5	3080	36.5	4930	38.0	2070	39.0
256	300	3020	33.5	2850	33.5	4670	34.5	1810	35.0
384	300	2840	31.0	2680	31.0	4480	32.0	1570	32.0
512	300	2650	28.0	2490	28.0	4310	29.5	1390	29.5
640	300	2410	25.0	2250	25.0	-	-	1150	26.0

ADSL over ISDN, Upstream, Noise model B and C, Loop 1-4

Payload Bitrate [kb/s]	f_T [kHz]	L1 [m]	L1 Y [dB] @f_T, @135Ω	L2 [m]	L2 Y [dB] @f_T, @135Ω	L3 [m]	L3 Y [dB] @f_T, @135Ω	L4 [m]	L4 Y [dB] @f_T, @135Ω
64	300	3110	44.5	4460	47.5	3560	45.5	3760	46.0
128	300	2960	42.0	4200	45.0	3400	43.0	3590	43.5
256	300	2740	39.0	3830	41.0	3160	40.0	3350	40.0
384	300	2580	37.0	3560	38.0	2990	37.5	3170	37.5
512	300	2380	34.0	3320	35.5	2810	35.0	2990	35.0
640	300	2150	30.5	2990	32.0	2570	31.5	2750	32.0

ADSL over ISDN, Upstream, Noise model B and C, Loop 5-8

Payload Bitrate [kb/s]	f_T [kHz]	L5 [m]	L5 Y [dB] @f_T, @135Ω	L6 [m]	L6 Y [dB] @f_T, @135Ω	L7 [m]	L7 Y [dB] @f_T, @135Ω	L8 [m]	L8 Y [dB] @f_T, @135Ω
64	300	3890	46.0	3730	46.0	5600	48.0	2680	47.5
128	300	3730	43.5	3560	43.5	5410	45.0	2550	46.0
256	300	3490	40.0	3320	40.0	5140	41.5	2280	42.0
384	300	3310	37.5	3140	37.5	4950	38.5	2040	38.5
512	300	3130	35.0	2960	35.0	4780	36.0	1850	36.0
640	300	2890	31.5	2720	31.5	4540	32.5	1640	33.0

ADSL over ISDN, Upstream, Noise model D, Loop 1-4

Payload Bitrate [kb/s]	f_T [kHz]	L1 [m]	L1 Y [dB] @f_T, @135Ω	L2 [m]	L2 Y [dB] @f_T, @135Ω	L3 [m]	L3 Y [dB] @f_T, @135Ω	L4 [m]	L4 Y [dB] @f_T, @135Ω
64	**300**	2990	**42.5**	4290	**46.0**	3440	**43.5**	3640	**44.0**
128	**300**	2840	**40.5**	4030	**43.0**	3280	**41.5**	3470	**42.0**
256	**300**	2610	**37.0**	3650	**39.0**	3040	**38.0**	3220	**38.0**
384	**300**	2440	**35.0**	3380	**36.0**	2850	**35.5**	3040	**35.5**
512	**300**	2250	**32.0**	3140	**33.5**	2680	**33.0**	2840	**33.0**
640	**300**	2020	**29.0**	2810	**30.0**	2440	**29.5**	2620	**29.5**

ADSL over ISDN, Upstream, Noise model D, Loop 5-8

Payload Bitrate [kb/s]	f_T [kHz]	L5 [m]	L5 Y [dB] @f_T, @135Ω	L6 [m]	L6 Y [dB] @f_T, @135Ω	L7 [m]	L7 Y [dB] @f_T, @135Ω	L8 [m]	L8 Y [dB] @f_T, @135Ω
64	**300**	3780	**44.0**	3610	**44.0**	5490	**46.0**	2560	**46.0**
128	**300**	3610	**42.0**	3440	**41.5**	5290	**43.5**	2430	**44.0**
256	**300**	3360	**38.0**	3190	**38.0**	5010	**39.5**	2150	**40.0**
384	**300**	3170	**35.5**	3010	**35.5**	4810	**36.5**	1910	**36.5**
512	**300**	2990	**33.0**	2830	**33.0**	4650	**34.0**	1710	**34.0**
640	**300**	2760	**29.5**	2590	**29.5**	4410	**31.0**	1510	**31.0**

Table 15: Performance objectives for upstream ADSL over ISDN when tested at various ADSL over ISDN noise models over various testloops. The electrical length Y (insertion loss at specified frequency f_T) is mandatory, the (estimated) physical lengths L1-L8 are informative.

ED NOTE These performance objectives are taken from contribution TD21 (Tioga), to be presented at the Sophia Antipolis meeting in 2001

7.4. Performance objectives for VDSL

ED NOTE To be inserted here in a future update of this document

8. Test Sequences

This clause specifies which subset of the performance objectives in clause [*] are to be verified by laboratory tests.

8.1. General test requirements

The test performance of the SDSL transceiver shall be such that the bit error ratio (BER) on the disturbed system is less than 10^{-7} , while transmitting a pseudo random bit sequence. The BER should be measured after at least 10^{9} bits have been transmitted.

The tests are carried out with a margin which indicates what increase of noise is allowed to ensure sufficient transmission quality. Network operators will calculate their own margins for planning purposes based on a knowledge of the relationship between this standard test set and their network characteristics.

8.1.1. Bit error ratio requirements

The xDSL system under test shall operate with a noise margin of at least +6 dB and a long-term bit error ratio of < 1 in 10^7 when operated over any of the test loops with the noise models and test conditions as specified in this clause.
The measurement period shall be at least 30 minutes. A long term performance test shall be performed for a period of not less than 24 hours to ensure long-term temporal stability (see sub-clause 8.3 and 8.4).

8.1.2. Measuring crosstalk noise margin

Before start-up of the xDSL modem under test, the level and shape of crosstalk noise is adjusted, while its level is probed at port Rx to meet the impairment level specification in sub-clause 6. 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.

For measuring the crosstalk margin, the crosstalk noise level of the impairment generator as defined in Tables 8 or 9, shall be increased by adjusting the gain of amplifier A1 in Figure 9, equally over the full frequency band of the xDSL system under test, until the bit error ratio is higher than 10^{-7}. This BER will be achieved at an increase of noise of **x** dB, with a small uncertainty of **Δx** dB. This value **x** is defined as the crosstalk noise margin with respect to a standard noise model.
The noise margins shall be measured for upstream as well as downstream transmission under test loop #1, #2, #3, and #4.

There is at present no concept of amplitude margin for the noise bursts of generator G7.

8.1.3. Impulse noise testing

The impulse noise tests will be carried out in the presence of crosstalk noise, at the levels specified in sub-clause 6. The transceiver link is subsequently activated, and the bit error ratio of the link is monitored. The link shall have a BER less than 10^{-7} for the duration of the test.

8.2. Test Sequences for SDSL

ED NOTE These text needs to be beautifyed

A test sequence as specified in table [*] shall be concluded. The testloops referred to are specified in figure [*]. The test loops are characterised by the insertion loss Y and/or the cable length L, which depend on the data rate to be transported and has to be scaled adequately.

N	Test Loop	Direction (NOTE 6)	Comments
1	#1 NOTE 1	Upstream	Y = 0 dB; Test noise A (NOTE 5, 7)
2	#2	Upstream	Y = Y1 (NOTE 2); Test noise A, C, & D (NOTE 7)
3	#3	Upstream	Y = Y1; Test noise D (NOTE 5, 7)
4	#4	Downstream	Y = Y1; Test noise A & C (NOTE 5, 7)
5	#5	Upstream	Y = Y1; Test noise B (NOTE 5, 7)
6	#6	Upstream	Y = Y1; Test noise A & C (NOTE 5, 7)
7	#7	Upstream	Y = Y1; Test noise A, B, C, & D (NOTE 5, 7)
8			Common mode rejection test (NOTE 4)
9	NOTE 3	NOTE 3	Y = Y2; Test noise is the worst noise corresponding to the worst path of test 1 to 7.BER < 10^{-7}
10	NOTE 3	NOTE 3	Y = Y3; No added impairment; Worst path of tests 1 to 7;BER < 10^{-8}
11	#2	Upstream	Y = Y1; Impulse test as described in <TBD>
12	As <TBD>	<TBD>	Micro interruption test as described in <TBD>

NOTE 1: Test Path = #1 means that the path under test shall be connected with test loop #1 as defined in figure 11.2.
NOTE 2: Y1 = Y dB (as specified in Table 10.3 for noise models B, C and D and in Table 10.2 for noise model A), Y2= Y1 - 10 dB, Y3 = Y1 + 3 dB.
NOTE 3: The tests are carried out on the worst test loop from tests 1 to 7. If there are no errors, then loop #3 Upstream is taken as default.
NOTE 4: The measuring arrangement for this test is specified in ITU-T Rec. O.9 [*].
NOTE 5: Only tested for lowest and highest data rate in Table [*] (that the equipment supports) and for asymmetric PSDs when supported.
NOTE 6: Upstream means that the unit under test is connected to the LT end of the test loop and downstream means that the unit under test is connected to the NT end of the test loop.
NOTE 7: The BER shall be less than 10^{-7} when the test noise is increased by 6 dB (this is equivalent to 6 dB of margin).

8.3. Test Sequences for ADSL over POTS

ED NOTE These test sequences are still under study within the ADSL project

8.4. Test Sequences for ADSL over ISDN

ED NOTE These test sequences are still under study within the ADSL project

8.5. Test Sequences for VDSL

ED NOTE These test sequences are still under study within the VDSL project

8.5.1. Upstream tests

Several xDSL performance tests shall be carried out to prove adequate upstream performance. These tests are specified in Table 16. Each symbolic name in this table refers to a specified noise model as defined in sub-clause 6. The injection of the impairment noise shall be at the LT side of the test-loop.

Test seq	Class (code)	Loops	G1	G2	G3	G4	G5	G6	G7
U1		1-8	G1.UP.A	G2.UP.A	-	G4	G5	-	-
U2		4	G1.UP.A	G2.UP.A	-	G4	G5	-	G7

Table 16: Test matrix with composition of noise models in the upstream tests (for further study)

8.5.2. Downstream tests

Several xDSL performance tests shall be carried out to prove adequate downstream performance. These tests are specified in Table 17. Each symbolic name in this table refers to a specified noise model as defined in sub-clause 6. The injection of the impairment noise shall be at the NT side of the test-loop.

Test seq	Class (code)	Loops	G1	G2	G3	G4	G5	G6	G7
D1		1-8	G1.DN.A	G2.DN.A	-	G4	G5	-	-
D2		2	G1.DN.A	G2.DN.A	-	G4	G5	-	G7
									-
									-
									-

Table 17: Test matrix with composition of noise models in the Downstream tests (for further study)

9. 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 xDSL transceiver should not reset, and the system should automatically reactivate.

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.

Ed. This whole issue is subject for further study

Annex A [normative]:
Line constants for the test loop-set

This appendix details the typical line constants for the cable sections in the testloops. The primary cable parameters vary with the frequency. Their typical values may be calculated at any frequency (up to a maximum frequency) by using empirical models.

A.1. Transmission and reflection of (cascaded) sections

The testloops are defined by one or a cascade of cable sections. The characteristics of each section are specified by means of primary cable parameters $\{Z_s, Y_p\}$ per unit length (L_0); Some of these parameters are given in tabular form; others by means of an analytical expression. This sub clause summarizes how to evaluate the relevan characteristics of cable sections (s-parameters) from the primairy parameters, and how evaluate these s-parameters for a cascade of cable sections.

Insertion loss and return loss of a cable section 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 $\mathbf{R_V} = 135\ \Omega$.

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

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

insertion loss: $1/s_{21}$
return loss: $1/s_{11}$

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

$$\mathbf{S} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} = \frac{1}{1 - s_{22a}\cdot s_{11b}} \cdot \begin{bmatrix} s_{11a} - \Delta_{sa}\cdot s_{11b} & s_{12b} \cdot s_{12a} \\ s_{21a} \cdot s_{21b} & s_{22b} - \Delta_{sb}\cdot s_{22a} \end{bmatrix} \qquad \Delta_s = s_{11}\cdot s_{22} - s_{12}\cdot s_{21}$$

A.2. Cable sections for the SDSL test loops

The primary cable parameters $Z_s = R_s + j\omega\cdot L_s$ and $Y_p = 0 + j\omega\cdot C_p$ per unit length are specified for various frequencies in Table A.1 and A.2. They are based on existing RLCG tables specified for HDSL [*], and extended up to 2 MHz. The values for frequencies in between are to be find by using a "cubic spline interpolation", as described in many textbooks, including [19].

		SDSL.PE04				**SDSL.PE05**				**SDSL.PE06**				**SDSL.PE08**		
freq [Hz] × 10^{+3}		**Rs [Ω/m] × 10^{-3}**	**Ls [H/m] × 10^{-9}**	**Cp [F/m] × 10^{-12}**		**Rs [Ω/m] × 10^{-3}**	**Ls [µH/m] × 10^{-9}**	**Cp [F/m] × 10^{-12}**		**Rs [Ω/m] × 10^{-3}**	**Ls [H/m] × 10^{-9}**	**Cp [F/m] × 10^{-12}**		**Rs [Ω/k] × 10^{-3}**	**Ls [H/k] × 10^{-9}**	**Cp [F/k] × 10^{-12}**
0		268	680	45.5		172	680	25		119	700	56		67	700	37.8
10		268	678	45.5		172	678	25		120	695	56		70.0	700	37.8
20		269	675	45.5		173	675	25		121	693	56		72.5	687	37.8
40		271	669	45.5		175	667	25		125	680	56		75.0	665	37.8
100		282	650	45.5		190	646	25		146	655	56		91.7	628	37.8
150		295	642	45.5		207	637	25		167	641	56		105	609	37.8
200		312	635	45.5		227	629	25		189	633	56		117	595	37.8
400		390	619	45.5		302	603	25		260	601	56		159	568	37.8
500		425	608	45.5		334	592	25		288	590	56		177.5	**543+17**	37.8
700		493	593	45.5		392	577	25		340	576	56		209	553	37.8
1000		582	582	45.5		466	572	25		405	570	56		250	547	37.8
2000		816	571	45.5		655	565	25		571	560	56		353	540	37.8

Table A.1 : Line constants for the cable sections in the SDSL test loops.

		SDSL.PVC032				SDSL.PVC04				SDSL.PVC063						
freq [Hz] × 10^{+3}		**Rs [Ω/m] × 10^{-3}**	**Ls [H/m] × 10^{-9}**	**Cp [F/m] × 10^{-12}**		**Rs [Ω/m] × 10^{-3}**	**Ls [μH/m] × 10^{-9}**	**Cp [F/m] × 10^{-12}**		**Rs [Ω/m] × 10^{-3}**	**Ls [H/m] × 10^{-9}**	**Cp [F/m] × 10^{-12}**				
0		419	650	120		268	650	120		108	635	120				
10		419	650	120		268	650	120		108	635	120				
20		419	650	120		268	650	120		108	635	120				
40		419	650	120		268	650	120		111	630	120				
100		427	647	120		281	635	120		141	604	120				
150		453	635	120		295	627	120		173	584	120				
200		493	621	120		311	619	120		207	560	120				
400		679	577	120		391	592	120		319	492	120				
500		750	560	120		426	579	120		361	469	120				
700		877	546	120		494	566	120		427	450	120				
1000		1041	545	120		584	559	120		510	442	120				
2000		1463	540	120		817	550	120		720	434	120				

Table A.2 : Line constants for the cable sections in the SDSL test loops.

A.3. Cable sections for the ADSL test loops

The primary cable parameters $Z_s=R_s+j\omega\cdot L_s$ and $Y_p=0+ j\omega\cdot C_p$ per unit length are specified for various frequencies in Table A.3 and A.4. The values for frequencies in between are to be find by using a "cubic spline interpolation", as described in many textbooks, including [19].

		ADSL.PE043				ADSL.PE04				ADSL.PE05		
freq [kHz]		**Rs [Ω/km]**	**Ls [μH/km]**	**Cp [nF/km]**		**Rs [Ω/km]**	**Ls [μH/km]**	**Cp [nF/km]**		**Rs [Ω/km]**	**Ls [μH/km]**	**Cp [nF/km]**
0,00		409,000	607,639	40,00		280,000	587,132	50,00		179,000	673,574	50,00
2,50		409,009	607,639	40,00		280,007	587,075	50,00		179,015	673,466	50,00
10,00		409,140	607,639	40,00		280,110	586,738	50,00		179,244	672,923	50,00
20,00		409,557	607,639	40,00		280,440	586,099	50,00		179,970	671,980	50,00
30,00		410,251	607,639	40,00		280,988	585,322	50,00		181,161	670,896	50,00
40,00		411,216	607,639	40,00		281,748	584,443	50,00		182,790	669,716	50,00
50,00		412,447	607,639	40,00		282,718	583,483	50,00		184,822	668,468	50,00
100,00		422,302	607,631	40,00		290,433	577,878	50,00		199,608	661,677	50,00
150,00		437,337	607,570	40,00		302,070	571,525	50,00		218,721	654,622	50,00
200,00		456,086	607,327	40,00		316,393	564,889	50,00		239,132	647,735	50,00
250,00		477,229	606,639	40,00		332,348	558,233	50,00		259,461	641,208	50,00
300,00		499,757	605,074	40,00		349,167	551,714	50,00		279,173	635,119	50,00
350,00		522,967	602,046	40,00		366,345	545,431	50,00		298,103	629,489	50,00
400,00		546,395	596,934	40,00		383,562	539,437	50,00		316,230	624,309	50,00
450,00		569,748	589,337	40,00		400,626	533,759	50,00		333,591	619,557	50,00
500,00		592,843	579,376	40,00		417,427	528,409	50,00		350,243	615,202	50,00
550,00		615,576	567,822	40,00		433,904	523,385	50,00		366,246	611,211	50,00
600,00		637,885	555,867	40,00		450,027	518,677	50,00		381,657	607,552	50,00
650,00		659,743	544,657	40,00		465,785	514,272	50,00		396,528	604,192	50,00
700,00		681,138	534,942	40,00		481,180	510,153	50,00		410,907	601,104	50,00
750,00		702,072	526,991	40,00		496,218	506,304	50,00		424,835	598,261	50,00
800,00		722,556	520,732	40,00		510,912	502,707	50,00		438,348	595,639	50,00
850,00		742,601	515,919	40,00		525,274	499,343	50,00		451,480	593,217	50,00
900,00		762,224	512,264	40,00		539,320	496,197	50,00		464,258	590,975	50,00
950,00		781,442	509,503	40,00		553,064	493,252	50,00		476,710	588,896	50,00
1000,00		800,272	507,415	40,00		566,521	490,494	50,00		488,857	586,966	50,00
1050,00		818,731	505,831	40,00		579,705	487,908	50,00		500,720	585,169	50,00
1100,00		836,837	504,623	40,00		592,628	485,481	50,00		512,317	583,495	50,00

Table A.3 : Line constants for the cable sections in the ADSL test loops.

		ADSL.PE063				ADSL.PE09						
freq [kHz]		Rs [Ω/km]	Ls [µH/km]	Cp [nF/km]		Rs [Ω/km]	Ls [µH/km]	Cp [nF/km]				
0,00		113,000	699,258	45,00		55,000	750,796	40,00				
2,50		113,028	697,943	45,00		55,088	745,504	40,00				
10,00		113,442	693,361	45,00		56,361	731,961	40,00				
20,00		114,737	687,008	45,00		59,941	716,775	40,00				
30,00		116,803	680,714	45,00		64,777	703,875	40,00				
40,00		119,523	674,593	45,00		70,127	692,707	40,00				
50,00		122,768	668,690	45,00		75,586	682,914	40,00				
100,00		143,115	642,718	45,00		100,769	647,496	40,00				
150,00		164,938	622,050	45,00		121,866	625,140	40,00				
200,00		185,689	605,496	45,00		140,075	609,652	40,00				
250,00		204,996	592,048	45,00		156,273	598,256	40,00				
300,00		222,961	580,960	45,00		170,987	589,504	40,00				
350,00		239,764	571,691	45,00		184,556	582,563	40,00				
400,00		255,575	563,845	45,00		197,208	576,919	40,00				
450,00		270,533	557,129	45,00		209,104	572,237	40,00				
500,00		284,753	551,323	45,00		220,365	568,287	40,00				
550,00		298,330	546,260	45,00		231,081	564,910	40,00				
600,00		311,339	541,809	45,00		241,326	561,988	40,00				
650,00		323,844	537,868	45,00		251,155	559,435	40,00				
700,00		335,897	534,358	45,00		260,615	557,183	40,00				
750,00		347,542	531,212	45,00		269,745	555,183	40,00				
800,00		358,819	528,378	45,00		278,577	553,394	40,00				
850,00		369,758	525,813	45,00		287,138	551,784	40,00				
900,00		380,388	523,480	45,00		295,452	550,327	40,00				
950,00		390,734	521,352	45,00		303,538	549,002	40,00				
1000,00		400,816	519,402	45,00		311,416	547,793	40,00				
1050,00		410,654	517,609	45,00		319,099	546,683	40,00				
1100,00		420,264	515,956	45,00		326,602	545,663	40,00				

Table A.4 : Line constants for the cable sections in the ADSL test loops.

A.4. Cable sections for Unified test loops

ED NOTE: The concept for a unified test loop approach for all xDSL systems is for further study

TP100 & TP180x	$Z_{s0}(f) = \left\{ \sqrt[4]{R_{oc}^4 + a_c \cdot f^2} + j \cdot 2\pi f \cdot \left(\frac{L_0 + L_\infty \cdot (f/f_m)^{Nb}}{1 + (f/f_m)^{Nb}} \right) \right\} \times \frac{1}{1000}$ $Y_{p0}(f) = \left\{ (g_0 \cdot f^{Nge}) + j \cdot 2\pi f \cdot (C_\infty + C_0 / f^{Nce}) \right\} \times \frac{1}{1000}$	[Ω/m] [S/m]
TP150 & TP100x	$Z_{s0}(\omega) = j\cdot\omega\cdot Z_{0\infty} \cdot 1/c + R_{ss00} \cdot (1 + K_l \cdot K_f \cdot (\chi \cdot \coth(4/3 \cdot \chi) - 3/4))$ $Y_{p0}(\omega) = j\cdot\omega/Z_{0\infty} \cdot 1/c \cdot (1 + (K_c - 1) / (1+(\omega/\omega_{c0})^N)) + \tan(\phi)/(Z_{0\infty}\cdot c) \cdot \omega^M$ $\chi = \chi(\omega) = (1+j)\cdot\sqrt{\frac{\omega}{2\pi}\cdot\frac{\mu_0}{R_{ss00}}\cdot\frac{1}{K_n \cdot K_f}}$, $\omega_{c0} = 2\pi\cdot f_{c0}$, $\mu_0 = 4\cdot\pi\cdot 10^{-7}$ [H/m],	[Ω/m] [S/m]

Table A.5 : The formal models, that may be used to calculate the cable parameters in the test loops, in combination with the line constants given in Table A.6 and A.7

Wire type	R_{oc} N_b	a_c g_0	R_{os} N_{ge}	a_s C_o	L_o C_∞	L_∞ N_{ce}	f_m
“TP100”	179 1.2	35.89e-3 0.5e-9	0.0 1.033	0.0 1e-9	0.695e-3 55e-9	585e-6 0.1	1e6
“TP180x”	41.16 1.1952665	1.2179771e-3 53.0e-9	0.0 0.88	0.0 31.778569e-9	1e-3 22.681213e-9	910.505e-6 0.11086674	174877.

Table A.6 : Line constants for the TP100 and TP180x cable sections in the test loops, that are defined by the BT#1 model.

	$Z_{0\infty}$	**c/c_0**	**R_{ss00}**	**$2\pi\cdot\tan(\phi)$**	**K_f**	**K_l**	**K_n**	**K_c**	**N**	**f_{c0}**	**M**
“**TP150**”	136.651	0.79766	0.168145	0.13115	0.72	1.2	1	1.08258	0.7	4521710	1
“**TP100x**”	97.4969	0.639405	0.177728	0.0189898	0.5	1.14	1	1	1	100000	1

Table A.7 : Line constants for the TP150 and TP100x cable sections in the test loops, that are defined by the KPN#1 model.

Annex B [informative]: Rationale behind the noise models

Various scenario's have been identified to be applied to xDSL testing. Each scenario is characterized in a technology mixture of different xDSL transmission systems. It is assumed that this mix is a fair representation of the technology mix in a multi-pair cable where the xDSL system under test is deployed.

For combining the individual disturbers into an *equivalent disturbance* of this mix, the FSAN noise combination method is used. The FSAN crosstalk sum for four individual PSD's is used for calculating the total equivalent disturbance of this technology mix. This sum equals for a mix of 4 technologies (P in W/Hz):

$$P = (P_1^{Kn} + P_2^{Kn} + P_3^{Kn} + P_4^{Kn})^{1/Kn}, \quad \text{at } K_n=1/0.6$$

The choosen technology mix is summarised below.

The noise models are based on the combined noise of different scenario's with xDSL systems.

B.1 Technology mix of SDSL noise models

The PSD profiles of the equivalent disturbance for SDSL testing are based on the technology mix summarized below

- ***Technology mix of model A (high penetration scenario)***

P_0	SDSL	+ 11.7 dB	(occupying about 90 wire pairs)
P_1	ISDN/2B1Q	+ 11.7 dB	(occupying about 90 wire pairs)
P_2	HDSL/2B1Q (2-pair)	+ 9.6 dB	(occupying about 40 wire pairs)
P_3	ADSL over POTS	+ 11.7 dB	(occupying about 90 wire pairs)
P_4	ADSL over ISDN	+ 11.7 dB	(occupying about 90 wire pairs)

- ***Technology mix of model B (medium penetration scenario)***

P_0	SDSL	+ 7.1 dB	(occupying about 15 wire pairs)
P_1	ISDN/2B1Q	+ 6.0 dB	(occupying about 10 wire pairs)
P_2	HDSL/2B1Q (2-pair)	+ 3.6 dB	(occupying about 4 wire pairs)
P_3	ADSL-lite	+ 6.0 dB	(occupying about 10 wire pairs)
P_4	ADSL over ISDN	+ 4.2 dB	(occupying about 5 wire pairs)

- ***Technology mix of model C (legacy scenario)***

P_0	SDSL	+ 7.1 dB	(occupying about 15 wire pairs)
P_1	ISDN/2B1Q	+ 6.0 dB	(occupying about 10 wire pairs)
P_2	HDSL/2B1Q (2-pair)	+ 3.6 dB	(occupying about 4 wire pairs)
P_3	ADSL-lite	+ 6.0 dB	(occupying about 10 wire pairs)
P_4	ADSL over ISDN	+ 4.2 dB	(occupying about 5 wire pairs)
P_5	ISDN-PRI/HDB3	+ 3.6 dB	(occupying about 4 wire pairs)

- ***Technology mix of model D (pure self-crosstalk scenario)***

P_0	SDSL	+ 10.1 dB	(occupying about 49 wire pairs)

NOTE 1 These numbers are a compromise found between several telcos and they **do not** reflect the actual environment in one specific network.

NOTE 2 The models approximate possible scenarios including ISDN/4B3T well enough. The difference of XA.LT.#, XA.NT.# between using ISDN/2B1Q and using ISDN/4B3T is negligible.

B.2. Technology mix of ADSL noise models

The PSD profiles of the equivalent disturbance for ADSL testing are based on the technology mix summarized below

- ***Technology mix of model A (high penetration scenario)***

P_1	ISDN/2B1Q	+ 11.7 dB	(occupying about 90 wire pairs)
P_2	HDSL/2B1Q (2-pair)	+ 9.6 dB	(occupying about 40 wire pairs)
P_3	ADSL (under test)	+ 13.5 dB	(occupying about 180 wire pairs)
P_4	SDSL (2.3Mb/s)	+ 11.7 dB	(occupying about 90 wire pairs)

- ***Technology mix of model B (medium penetration scenario)***

P_1	ISDN/2B1Q	+ 6.0 dB	(occupying about 10 wire pairs)
P_2	HDSL/2B1Q (2-pair)	+ 3.6 dB	(occupying about 4 wire pairs)
P_3	ADSL (under test)	+ 7.1 dB	(occupying about 15 wire pairs)
P_4	SDSL (2.3Mb/s)	+ 7.1 dB	(occupying about 15 wire pairs)

- ***Technology mix of model C (legacy scenario)***

P_1	ISDN/2B1Q	+ 6.0 dB	(occupying about 10 wire pairs)
P_2	HDSL/2B1Q (2-pair)	+ 3.6 dB	(occupying about 4 wire pairs)
P_3	ADSL (under test)	+ 7.1 dB	(occupying about 15 wire pairs)
P_4	SDSL (2.3Mb/s)	+ 7.1 dB	(occupying about 15 wire pairs)
P_5	ISDN-PRI/HDB3	+ 3.6 dB	(occupying about 4 wire pairs)

- ***Technology mix of model D (pure self-crosstalk scenario)***

P_1	ADSL (under test)	+ 10.1 dB	(occupying about 49 wire pairs)

NOTE 1 These numbers are a compromise found between several telcos and they **do not** reflect the actual environment in one specific network.

NOTE 2 The models approximate possible scenarios including ISDN/4B3T well enough. The difference of noise X.LT.#, X.NT.# between using ISDN/2B1Q and using ISDN/4B3T is negligible.

NOTE 3 The technology "ADSL" in this mix is "ADSL over POTS" when ADSL over POTS is tested, and "ADSL over ISDN: when ADSL over ISDN is tested.

B.3. Assumptions on individual PSDs

The individual systems in this technology mix can be described by simplified PSD masks, and the break frequencies of these masks are summarised in table 18 and 20. The PSD masks in table 18 are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.

ISDN 2B1Q	***135 Ω***
[Hz]	**[dBm/Hz]**
1	-31.8
15k	-31.8
30k	-33.5
45k	-36.6
60k	-42.2
75k	-55
85k	-55
100k	-48
114k	-48
300k	-69
301k	-79
500k	-90
1.4M	-90
3.637M	-120
30M	-120

ISDN 4B3T [1]	***See footnote 150Ω***
[Hz]	**[dBm/Hz]**
1	-30
50k	-30
300k	-67
301k	-74
1M	-74
4.043M	-120
30M	-120

HDSL 2B1Q	***2 pair 135 Ω***
[Hz]	**[dBm/Hz]**
1	-40.2
100k	-40.2
200k	-41.6
300k	-44.2
400k	-49.7
500k	-61.5
570k	-80
600k	-80
650k	-72
755k	-72
2.92M	-119
30M	-119

HDSL CAP	***2 pair 135 Ω***
[Hz]	**[dBm/Hz]**
1	-57
3.98k	-57
21.5k	-43
39.02k	-40
237.58k	-40
255.10k	-43
272.62k	-60
297.00k	-90
1.188M	-120
30M	-120

ADSL over POTS DMT	***Up 100 Ω***
[Hz]	**[dBm/Hz]**
1	-97.5
3.99k	-97.5
4k	-92.5
25.875k	-37.5
138k	-37.5
307k	-90
1.221M	-90
1.630M	-110
30M	-110

ADSL over POTS DMT	***Down 100 Ω***
[Hz]	**[dBm/Hz]**
1	-97.5
3.99k	-97.5
4k	-92.5
25.875k	-39.5
1.104M	-39.5
3.093M	-90
4.545M	-110
30M	-110

ADSL over ISDN DMT	***Up 100 Ω***
[Hz]	**[dBm/Hz]**
1	-90
50k	-90
80k	-81.9
138k	-37.5
276k	-37.5
614k	-90
1.221M	-90
1.630M	-110
30M	-110

ADSL over ISDN DMT	***Down 100 Ω***
[Hz]	**[dBm/Hz]**
1	-90
50k	-90
80k	-81.9
138k	-39.5
1.104M	-39.5
3.093M	-90
4.545M	-110
30M	-110

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[1] This ISDN/3B4T PSD is based on the ***mask*** that is specified in ETSI standards, and not on a ***template*** for the expected average value. Using this PSD for performance simulation purposes may therefore cause results that are a bit pessimistic. This has no consequences to the SDSL noise models, since the ISDN/3B4T PSD is not used here. An update of this PSD, for simulation purposes in general, is for further study.

ADSL-lite DMT	***Up 100 Ω***
[Hz]	**[dBm/Hz]**
1	-97.5
3.99k	-97.5
4k	-92.5
25.875k	-37.5
138k	-37.5
307k	-90
1.221M	-90
1.630M	-110
30M	-110

ADSL-lite DMT	***down 100 Ω***
[Hz]	**[dBm/Hz]**
1	-97.5
3.99k	-97.5
4k	-92.5
80k	-72.5
138.0k	-44.2
138.1k	-39.5
552k	-39.5
956k	-65
1.800M	-65
2.290M	-90
3.093M	-90
4.545M	-110
30M	-110

Table 18: Break frequencies of the PSD masks of individual transmission systems. ADSL over ISDN refers to the case of ISDN-2B1Q. For reasons of simplicity, the brick walls at 4 kHz are modelled as step between 3.99 kHz to 4 kHz. Note that the PSD's of ISDN-BA (4B3T) and HDSL/2 (CAP) are included here for completeness, but are not used to calculate the noise models.

$$P(f) = \frac{2}{f_{sym}} \cdot \frac{\mathrm{sinc}^2(f/f_{sym})}{1 + (f/f_{3dB})^{2\cdot N}} \cdot {K_N}^2 \cdot P_0 \qquad [\mathrm{W/Hz}]$$

$P_0 = 14.5$ dBm ≈ 28.18 mW; Rs=135 Ω;
$f_{sym} = 2.312/3$ MHz; $f_{3dB} = f_{sym}/2$; N=6; $K_N = 1.14$
$\mathrm{sinc}(x) = \sin(\pi\cdot x) / (\pi\cdot x)$

Table 19: PSD mask of the SDSL system, as a function of the frequency. (assuming 2.304 kb/s datarate, 8kb/s overhead, 3 bits per symbol)

$$P(f) = \frac{2}{f_{sym}} \cdot \frac{\mathrm{sinc}^2(f/f_{sym}-1)}{1 + (f/f_{3dB})^{2\cdot N}} \cdot P_0 \quad [\mathrm{W/Hz}]$$

$P_0 = 12.4$ mW $= 10.92$ dBm; Rs=130 Ω;
$f_{sym} = 1.024$ MHz; $f_{3dB} = f_{sym}$; N=0.9
$\mathrm{sinc}(x) = \sin(\pi\cdot x) / (\pi\cdot x)$

Table 20: PSD mask of the ISDN-PRI (HDB3) system, as a function of the frequency.

The PSD levels, of the sources in table 18 and 20, are defined, when terminated by their associated source impedances R_s. The calculated noise models take account for the (minor) power drop caused by the fact that the interfering systems are not terminated with their nominal source impedance. They are all terminated with the cable impedance. The corresponding correction factor is calculated as follows:
Let P_V be the output power spectral density of these sources when terminated with the normalized test impedance R_V, level P_s when terminated with the source impedance R_s, and level P when terminated by the cable impedance. Calculating the output level of a source with impedance R_s by the normalized test impedance R_V requires the following correction in the output level to their nominal level:

$$P_V = \left(2 \cdot \frac{\sqrt{(R_v \cdot R_s)}}{R_v + R_s}\right)^2 \times P_s$$

Terminating a 150Ω system by 135Ω requires –0.0120 dB correction in P_s.
Terminating a 135Ω system by 135Ω requires –0.0000 dB correction in P_s.

Terminating a 120Ω system by 135Ω requires –0.0151 dB correction in P_s.
Terminating a 110Ω system by 135Ω requires –0.0455 dB correction in P_s.
Terminating a 100Ω system by 135Ω requires –0.0974 dB correction in P_s.

In a real access network, this correction is slightly different, because the systems are terminated with the cable impedance in stead of the normalized test impedance R_V. For reasons of simplicity, (all cables are different in impedance), the noise models are based on the simplification that all interfering systems are terminated with the normalized test impedance R_V=135Ω.

Annex C [informative]: Realistic Impulsive noise models

In the body of this document, tests are described which test the implementation of measures to suppress impulsive noise (see sub-clause 6.3.7). For practical reasons a standards test cannot use a realistic representation of impulsive noise for this purpose.
This appendix is concerned with impulsive noise and its realistic representation, for use in simulation and emulation. Simulations will typically be used by modem designers to determine the suppression measures to be implemented. Emulation will typically be used by telcos to estimate a modem's performance in a real network.

C.1. Noise Model

> Ed. This whole issue is the subject of ongoing study. See also TD18/19/20/21 from Edinburgh

Annex D [informative]: References

[1] Rob.F.M. van den Brink. *Cable Reference Models for Simulating Metallic Access Networks*, ETSI STC TM6 document, TM6(97)02, revision 3, June 1998.

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[3] **ETSI-TM6(97)05:** "*Transmission and Multiplexing (TM); Asymmetric Digital Subscriber Line (**ADSL**); Coexistence of ADSL and ISDN-BA on the same pair*", ETSI, DTS/TM-06006 (Draft) V 1.0.1, September 1998

[4] **T1.413, issue 1:** "*Network and customer installation interfaces - Asymmetrical Digital Subscriber Line (**ADSL**) Metallic Interface*", ANSI, American National Standardization Institute, Issue 1, August 1995.

[5] **T1.413, issue 2:** "*Standards Project for Interfaces Relating to Carrier to Customer Connection of Asymmetrical Digital Subscriber Line (**ADSL**) Equipment*", ANSI, American National Standardization Institute, draft specification issue 2, T1E1.4/98-007R5, Sept 1998.

[6] Rob F.M. van den Brink, KPN, *Proposal for SDSL performance tests*, ETSI-TM6 contribution TD27 (984t27a0), Vienna, Sept 1998.

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