ETSI STC TM6

(ACCESS TRANSMISSION SYSTEMS ON METALLIC CABLES)

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Performance tests for SDSL, ADSL and other long-range 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 SDSL, that have gained some support. The primary purpose is SDSL, but consensus has grown within ETSI-TM6 to define one general performance tests for all long range xDSL systems, including ADSL.
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 described in [8,9,10], and
- the testloops as described in [14] and preceded by [15,16,17].

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1. Transmission performance tests

The purpose of transmission performance tests is to stress xDSL transceivers in a way that is representative to a high penitration of systems scenario in operational access networks. This high penitration approach enables operators to define deployment rules that apply to most operational situations. It means also that in individual operational cases, characterised by lower noise levels and/or insertion loss values, the xDSL system under test may perform better than tested

The performance requirements given in this clause are dedicated to SDSL transceivers, but the concept is upgradeble to other systems such as “ADSL over ISDN”. The design impedance $\mathbf{R_V}$ is 135Ω. All spectra are representing single sided power spectral densities (PSD’s).

2. 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.

2.1. Test set-up definition

Figure **1** illustrates the functional description of the test set-up. It includes:

- The test loops, as specified in sub-clause 3;
- An adding element to add the impairment noise (a mix of random, impulsive and harmonic noise), as specified in sub-clause 4;
- A high impedance, and well balanced (e.g. better than 60 dB across the whole band of the xDSL system under test) differential voltage probe connected with level detectors such as a spectrum analyser or a true rms volt meter.

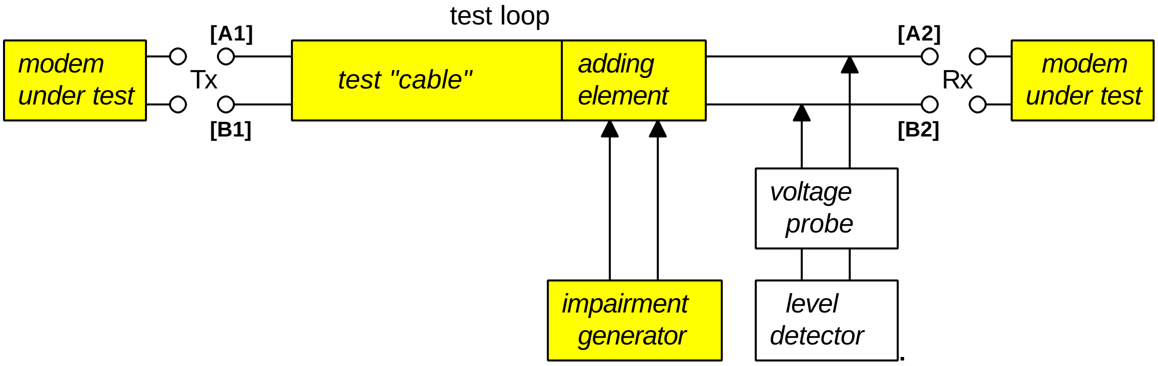


Figure 1: Functional description of the set-up of the performance tests. When external splitters are required for the xDSL system under test (for POTS or ISDN signals), this splitter shall be included in the modem under test.

The two-port characteristics (transfer function, impedance) of the test-loop, as specified in sub-clause 3, 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 3, shall always be used for calibrating and verifying the correct settings of generators G1-G7, as specified in sub-clause 4, 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 4. The level that is specified in sub-clause 4 is the level at port Rx, measured between node A2 and B2, while port Tx as well as port Rx are terminated with the design impedance $\mathbf{R_V}$. These impedances shall be passive when the transceiver impedance in the switched-off mode is different from this value.

2.2. 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 adequatean 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

2.3. Signal and noise level definitions

The signal and noise levels are probed with a well balanced differential voltage probe, and the differential impedance between the tips of 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].

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 design 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.

3. 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

3.1. Functional description

The test loops in figure 1 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 (see figure 2). 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 (see Figure 3). 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.
- One test loop includes 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.
- Loop #1 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.

> **ED NOTE** It is posible that the approach of "normalizing" the electrical length can be improved by a more sophisticated approach (e.g. equivalent loss, impulse response). In that case, the length of each loop remains specified in terms of electrical length (at a well chosen center frequency) but each loop has a (slightly) different electrical length. Such an improvement has only impact to the numbers in table 1 and 2, and not on the topology description in figure 2. The numbers in table 1 and 2 are for further study.

3.2. Testloop topology

The topology of the loops is specified in figure 1. The transfer function of all the loops for each payload bit-rate is shown in Figure 2. The variation of input impedance for the various test loops is shown in Figure 3. The two-port cable models that are used to describe the individual sections of the loops are specified in Annex A.

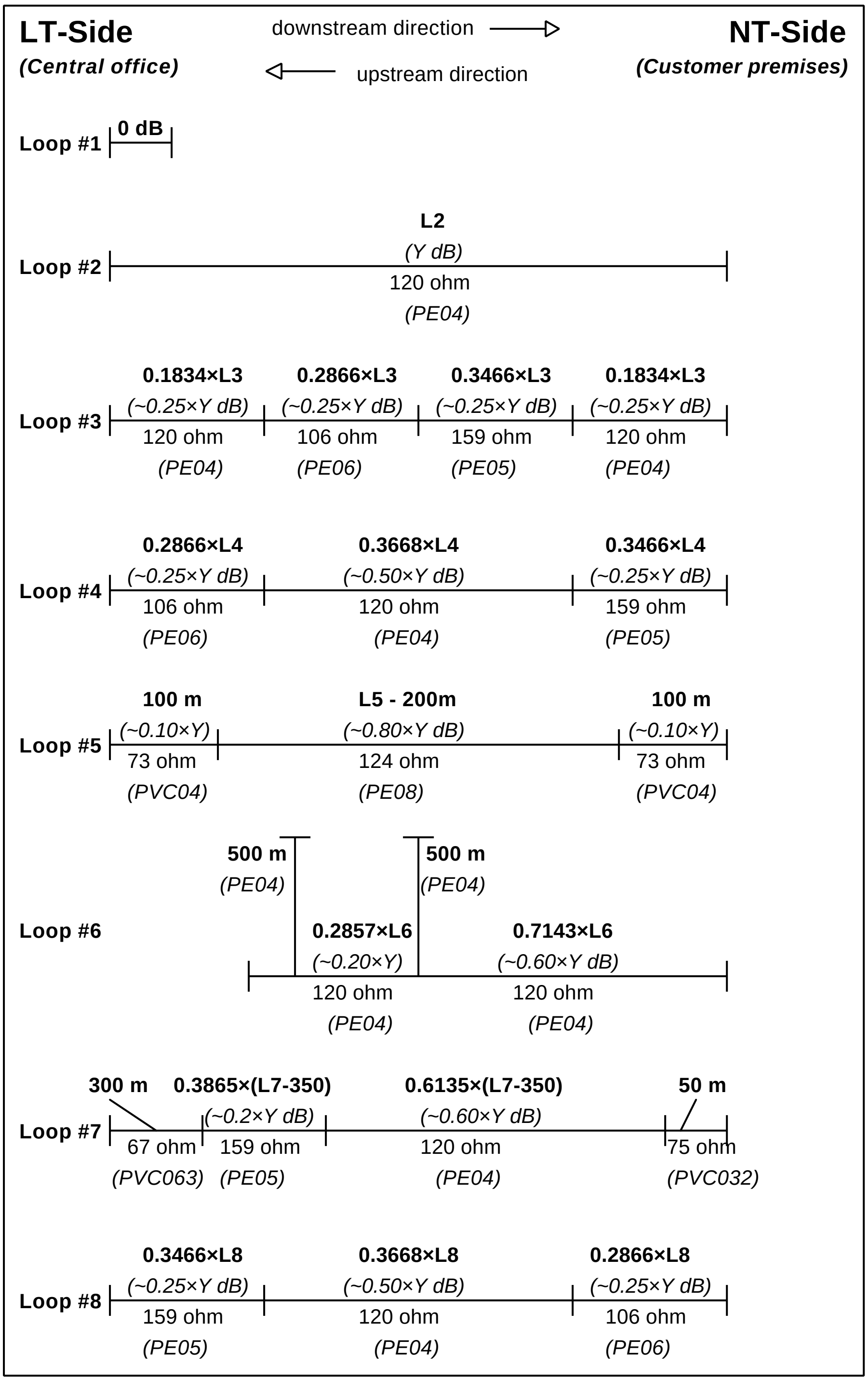


Figure 1: Test loop topology, that is made as similar as possible to existing HDSL test loops. Mark that loop#8 is the same as loop #4, but reversed in transmission direction. The physical lengths L1 to L8 are specified in table 1. The symbolic labels (e.g. "PE04") refer to the two-port cable models 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.

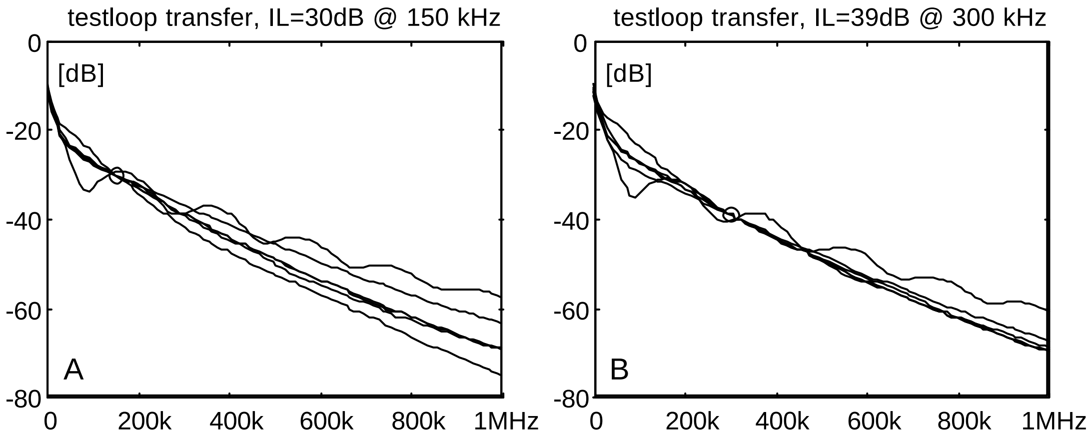


Figure 2: Examples of calculated transfer functions (into 135W) of test-loop #2 to #8. In figure 3a the electrical length of each loop is normalized at 150 kHz (30 dB loss in this example), and in figure 3b at 300 kHz (39 dB in this example). The choise for test frequencyies, as specified in table 1, is closely related to the PSD of the xDSL modem under test, and this PSD may vary with the payload bitrate.

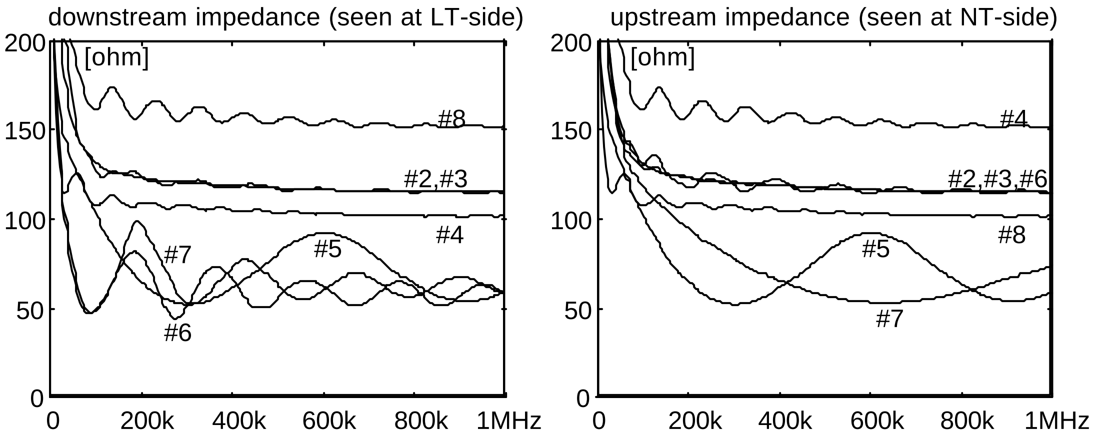


Figure 3: Calculated variation of input impedance (absolute value) of testloop #2 to #8. When the cable is relatively long, these impedances become more or less length independent.

3.3. Testloop length

The length of each test loop for SDSL modems is specified in table 1. The specified insertion loss at the specified test frequency and 135Ω impedance (*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 is chosen to be a typical mid-band frequency in the spectrum of long range xDSL systems. The length is chosen to be a typical maximum value that can be handled correctly by the xDSL 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.

Payload Bitrate [kb/s]	f_T [kHz]	IL_0 [dB] @f_T, @135 W	L1 [m]	L2 [m]	L3 [m]	L4 [m]	L5 [m]	L6 [m] =0.8×L2	L7 [m]	L8 [m] = L4
384	150	**47**.13	< 3	4500	6096.0	6104.0	12218.0	3600.0	5175.0	6104.0
512	150	**43**.56	< 3	4160	5635.0	5641.0	11221.0	3328.0	4767.0	5641.0
768	150	**38**.33	< 3	3662	4960.7	4962.0	9759.7	2929.6	4154.7	4962.0
1024	150	**34**.77	< 3	3323	4496.5	4501.8	8765.7	2658.4	3728.0	4501.8
1280	150	**32**.94	< 3	3148	4256.8	4264.1	8251.9	2518.4	3510.4	4264.1
1536	150	**29**.03	< 3	2776	3750.4	3755.0	7161.2	2220.8	3065.3	3755.0
2048	150	**25**.09	< 3	2400	3229.1	3235.2	6059.0	1920.0	2626.1	3235.2
2304	150	**23**.75	< 3	2273	3055.3	3061.8	5683.9	1818.4	2475.6	3061.8

Table 1: Approximation for the physical length of the SDSL testloops, calculated for different electrical lengths.

ED NOTE The numbers here are an example only. The insertion loss values at 150 kHz were taken from TD8 and TD10 [16,17] (Edinburgh). When the PSD for SDSL has been defined, it is plausible that these values may change. The same applies for the 150 kHz test frequencies. The PSD may give reason to make this bitrate dependent if it suits better to the chosen PSD. This topic is for further study.

Realistic electrical length values shall be based on the results of performance simulations that show what realistic values are.

Payload Bitrate [kb/s]	f_T [kHz]	IL_0 [dB] @f_T, @135 W	L1 [m]	L2 [m]	L3 [m]	L4 [m]	L5 [m]	L6 [m] =0.8×L2	L7 [m]	L8 [m] = L4

Table 2: Approximation for the physical length of the ADSL testloops, calculated for different electrical lengths.

ED NOTE This table is intended for future adoption of these test loops for ADSL.The topology of these new ADSL loops are intended to be the same as for SDSL. The length of these new ADSL testloops are for further study

3.4. 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 1, 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.

4. Impairment generator

The noise that the impairment generator injects into the test setup is frequency dependent, is dependent on the length of the testloop and is also different for downstream performance tests and upstream performance tests. Figure 5 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 6 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.

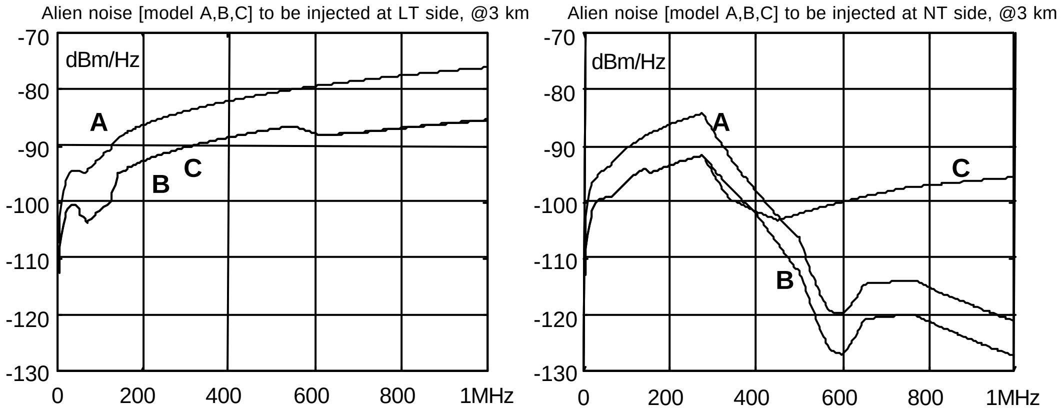


Figure 5: Examples of alien noise spectra that are to be injected into the test setup, while testing SDSL systems. This is the noise, resulting from three of the four noise models for SDSL, in the case that the length of testloop #2 is fixed at 3 km.

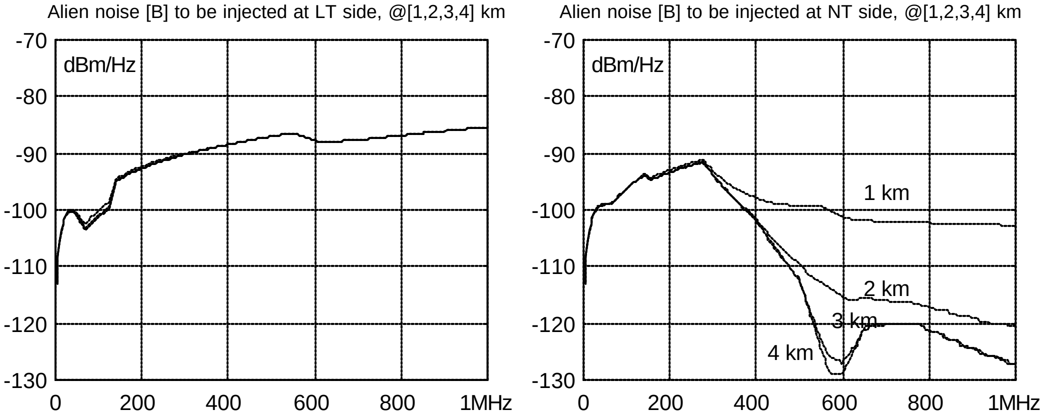


Figure 6: Examples of alien noise spectra that are to be injected into the test setup, while testing SDSL systems. This is the alien noise, resulting from noise model B for SDSL, in the case that the length of testloop #2 varies from 1 km to 4 km. This demonstrates that the test noise is length dependent, to represent the FEXT in real access network cables.

The definition of the impairment noise for xDSL performance tests is very complex and for the purposes of this TS it has been broken down into smaller, more easily specified components. These separate, and uncorrelated, impairment "generators" 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.

4.1. Functional description

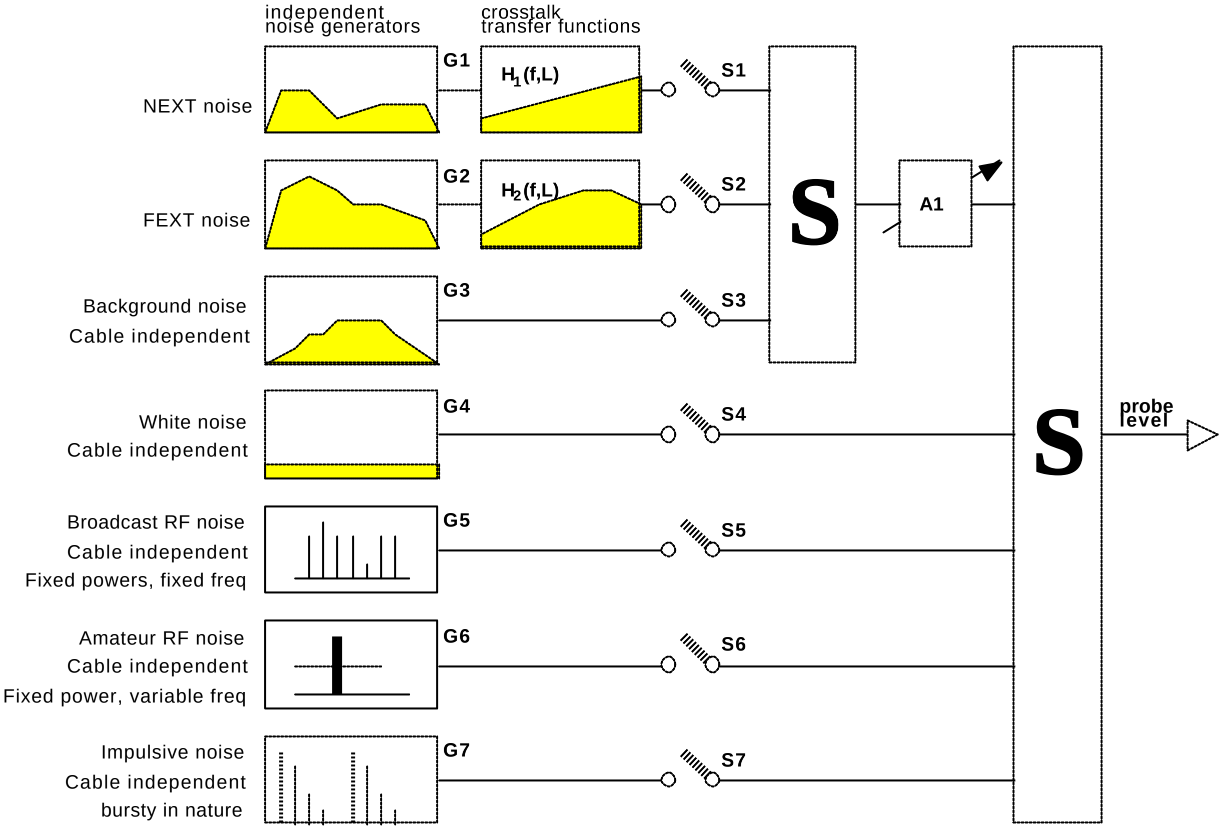
Figure 7 defines a functional diagram of the composite impairment noise. It defines a functional description of the combined impairment noise, as it must be probed at the receiver input of the xDSL transceiver under test. This probing is defined in sub-clause 2.3.

The functional diagram has the following elements:

- The seven impairment "generators" G1 to G7 generate noise as defined in sub-clause 4.3.1 to 4.3.7. 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 4.2. 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 4.2. 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 5.2. 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 7. 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 7: 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.

> **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 ***reference scenario*** to demonstrate the difference between a cable filled with SDSL only, or filled with a mixture of xDSL techniques.

Each test has its own impairment specification, as specified in clause 5. 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.

4.2. 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 7 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 1 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 3 shall be used as cross-talk transfer functions in the impairment generator.

$H_1(f, L) = K_{xn} \times (f/f_0)^{0.75} \times \sqrt{1 - \lvert s_T(f, L)\rvert^4}$ $H_2(f, L) = K_{xf} \times (f/f_0) \times \sqrt{(L/L_0)} \times \lvert s_T(f, L)\rvert$
$K_{xn} = 10^{(-50/20)} \approx 0.0032$, $f_0 = 1$ MHz $K_{xf} = 10^{(-45/20)} \approx 0.0056$, $L_0 = 1$ km $s_{T0}(f, L)$ = averaged test loop transfer function

Table 3 : Definition of the crosstalk transfer functions

NOTE: These values are rounded values, and chosen to be close to the ANSI T1E1.4 VDSL draft System Requirements (which are consistent with [*]). This choice is equivalent to 50 dB NEXT loss and 45 dB EL-FEXT loss at a cable section of 1 km. At this moment, it is by no means sure that these are reasonable values to represent the 'average' European cables. The few measurements that are available for European cables demonstrate sometimes significant differences from the above values. This is an area of further study.

4.3. Individual impairment generators

4.3.1. NEXT noise generator [G1.xx]

The NEXT noise generator represents 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 4.2, will represent the contribution of all NEXT to the composite impairment noise of the test.

The PSD of this noise generator is a combination of the self crosstalk and alien crosstalk profiles, as specified in sub-clause 4.4.1. These profiles shall be met for all frequencies between 1 kHz to 1 MHz. For measuring PSD the measurement bandwidth shall be equal to or less than 1 kHz.

G1.LT.# = (XS.LT.# ♦ XA.LT.#)
G1.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 "XS.LT.#" and "XS.NT.#" refers to the self crosstalk profiles, as defined in 4.4.1.1
- Symbol "XA.LT.#" and "XA.NT.#" refers to the alien crosstalk profiles, as defined in 4.4.1.2
- 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.

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 4.2.

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 4.4.2.

4.3.2. FEXT noise generator [G2.xx]

The FEXT noise generator represents 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 4.2, will represent the contribution of all FEXT to the composite impairment noise of the test.

The PSD of this noise generator is a combination of the self crosstalk and the alien crosstalk profiles, as specified in sub-clause 4.4.1. These profiles shall be met for all frequencies between 1 kHz to 1 MHz. For measuring PSD the measurement bandwidth shall be equal to or less than 1 kHz.

G2.LT.# = (XS.NT.# ♦ XA.NT.#)
G2.NT.# = (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 “XS.LT.#” and “XS.NT.#” refers to the self crosstalk profiles, as defined in 4.4.1.1.
- Symbol “XA.LT.#” and “XA.NT.#” refers to the alien crosstalk profiles, as defined in 4.4.1.2.
- 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.

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 4.2.

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 4.4.2.

4.3.3. Background noise generator [G3]

The background noise generator is Inactive and set to zero.

4.3.4. White noise generator [G4]

The white noise generator has a fixed, frequency independent value, and is set to –140 dBm/Hz into 135 Ω. 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 4.4.2.

4.3.5. Broadcast RF noise generator [G5]

The broadcast RF noise generator represents the discrete tone-line interference caused by amplitude modulated broadcast transmissions in the SW, MW and LW bands which ingress into the differential or transmission mode of the wire-pair. These interference sources have more temporal stability than the amateur/ham interference because their carrier is not suppressed. The modulation index (MI) is usually up to 80%. These signals are detectable using a spectrum analyser and result in line spectra of varying amplitude in the frequency band of the xDSL system under test. Maximum observable 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.
Several noise models are specified in this sub-clause. The average minimum power of each carrier frequency is specified in Table [*] for each model.

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

4.3.6. 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.

4.3.7. Impulse noise generator [G7]

A test with this noise generator is required to prove the burst noise immunity of the VDSL transceiver. This immunity shall be demonstrated on short and long loops and noise to model cross-talk and RFI. Further test details are given in sub-clause 5.

The noise shall consist of burst of Additive White Gaussian Noise injected onto the line with sufficient power to ensure effective erasure of the data for the period of the burst, i.e. the bit error ratio during the burst should be approximately 0.5. The noise burst shall be applied regularly at a repetition rate of at least 1 Hz.

Ed. This whole issue is subject for further study

4.4. Profiles of the individual impairment generators

4.4.1. Frequency domain profiles of generator G1 and G2

Crosstalk noise represents all impairment that originates from systems connected to adjacent wire pairs, and that are coupled to the wires of the xDSL system under test. This noise spectrum varies with the electrical length of the testloop.

To simplify matters, the definition of crosstalk noise has been broken down into smaller, more easily specified components. Noise generator G1 and G2 represent the ‘equivalent disturbance’, of many disturbers in a real scenario, as if all disturbers are colocated at the ends of the testloops. This approach has isolated their definition from the NEXT and FEXT coupling functions of the cable.

This sub-clause specifies the PSD profiles of these two generators.

4.4.1.1. Self crosstalk profiles.

The noise profile of self crosstalk is implementation specific of the xDSL 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 xDSL system under test, as it can be observed at the Tx port of the test set-up as described in sub clause 2.1. The measurement bandwidth for PSD shall be 1 kHz. or less.

For SDSL, four noise noise models for self crosstalk have been defined, and for each noise model, two spectral profiles are identified: one for stressing upstream signals and one for stressing downstream signals.

- The profiles XS.LT.# describe the self crosstalk portion of an ‘equivalent disturber’ that is virtually co-located at the LT end of the testloop. This equivalent disturber is represented by generator G1, when stressing upstream signals, and by generator G2 when stressing downstream signals. The self-crosstalk profiles are specified in table 4.
- The profiles XS.NT.# describe the self crosstalk portion of an ‘equivalent disturber’ that is virtually co-located at the NT end of the testloop. This equivalent disturber is represented by

generator G2, when stressing upstream signals, and by generator G1 when stressing downstream signals. The self-crosstalk profiles are specified in table 4.

In this nomenclature is “#” a placeholder for model “A”, “B” ,”C” or “D”.

	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. The different noise models use different Gain factors.

4.4.1.2. Alien crosstalk profiles.

For SDSL, four noise noise models for alien crosstalk have been defined, although the alien noise in model D is made inactive (self crosstalk only). For each model, two spectral profiles are identified: one for stressing upstream signals and one for stressing downstream signals. Each PSD profile originates from a mix of disturbers, as described in annex B.

- The profiles XA.LT.# describe the alien crosstalk portion of an ‘equivalent disturber’ that is virtually co-located at the LT end of the testloop. This equivalent disturber is represented by generator G1, when stressing upstream signals, and by generator G2 when stressing downstream signals. The alien crosstalk-profiles are specified in table 5, in terms of break frequencies.
- The profiles XA.NT.# describe the alien crosstalk portion of an ‘equivalent disturber’ that is virtually co-located at the NT end of the testloop. This equivalent disturber is represented by generator G2, when stressing upstream signals, and by generator G1 when stressing downstream signals. The alien crosstalk-profiles are specified in table 6, in terms of break frequencies.

In this nomenclature is “#” a placeholder for model “A”, “B” ,”C” or “D”.

XA.LT.A [Hz]	*135W* [dBm/Hz]	XA.LT.B [Hz]	*135W* [dBm/Hz]	XA.LT.C [Hz]	*135W* [dBm/Hz]	XA.LT.D [Hz]	*135W* [dBm/Hz]
1	-20.0	1	-25.7	1	-25.7		
15 k	-20.0	15 k	-25.7	15 k	-25.7		
30 k	-21.5	30 k	-27.4	30 k	-27.4	*ALL*	*ZERO*
67 k	-27.0	45 k	-30.3	45 k	-30.3		
125 k	-27.0	70 k	-36.3	70 k	-36.3		
138 k	-25.7	127 k	-36.3	127 k	-36.3		
400 k	-26.1	138 k	-32.1	138 k	-32.1		
1104 k	-26.1	400 k	-32.5	400 k	-32.5		
2.5 M	-66.2	550 k	-32.5	550 k	-32.5		
4.55 M	-96.5	610 k	-34.8	610 k	-34.8		
30 M	-96.5	700 k	-35.4	700 k	-35.3		
		1104 k	-35.4	1104 k	-35.3		
		4.55 M	-103.0	1.85 M	-58.5		
		30 M	-103.0	22.4 M	-103.0		
				30 M	-103.0		

Table 5: Break frequencies of the “XA.LT.#” PSD profiles that specify the alien noise spectra as used in sub-clause 4.3.1 and 4.3.2. 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 135W resistive load.

XA.NT. A [Hz]	135 W [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 W [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 W [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 W [dBm/Hz]
ALL	*ZERO*

Table 6: Break frequencies of the "XA.NT.#" PSD profiles that specify the alien noise spectra as used in sub-clause 4.3.1 and 4.3.2. 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 135W resistive load.

4.4.2. Time domain profiles of generator G1-G4

The noise, as specified in the frequency domain in sub-clause 4.3.1 to 4.3.4, 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 8 and defined in table 7.

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:

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

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).

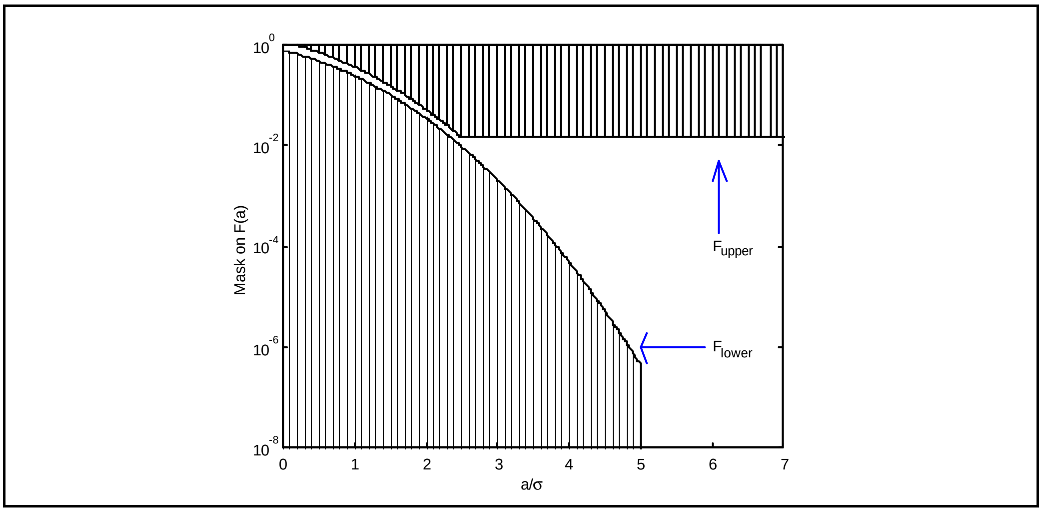


Figure 8: Mask for the Amplitude Distribution Function: the non-shaded area is the allowed region. The boundaries of the mask are specified in Table 7.

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

parameter	**value**
crest factor	CF = 5
gaussian gap	$\varepsilon = 0.1$
	A = CF/2 = 2.5

Table 7: Upper and lower boundaries of the amplitude distribution function of the noise.

The meaning of the parameters in table 7 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.

5. Transmission Performance tests

5.1. 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 5.3 and 5.4).

5.2. Measuring noise margin

At start-up, the level and shape of crosstalk noise or impulse noise are adjusted, while their level is probed at port Rx to meet the impairment level specification in sub-clause 4. This relative level is referred to as 0 dB. The transceiver link is subsequently activated, and the bit error ratio of the link is monitored.

5.2.1. Measuring crosstalk noise margin

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 7, 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 **Dx** 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.

5.2.2. Measuring impulse noise margin

Ed. This whole issue is subject for further study

5.3. Upstream tests

Several xDSL performance tests shall be carried out to prove adequate upstream performance. These tests are specified in Table 8. Each symbolic name in this table refers to a specified noise model as defined in sub-clause 4. The injection of the impairment noise shall be at the LT side of the test-loop.

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

Table 8: Test matrix with composition of noise models in the upstream tests (for further study)

5.4. Downstream tests

Several xDSL performance tests shall be carried out to prove adequate downstream performance. These tests are specified in Table 9. Each symbolic name in this table refers to a specified noise model as defined in sub-clause 4. The injection of the impairment noise shall be at the NT side of the test-loop.

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

Table 9: Test matrix with composition of noise models in the Downstream tests (for further study)

6. 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 [*] MHz) by using empirical models. The formulas in Table A.1 define the formal model, and the line constants in Table A.2 and Table A.3 the associated parameters.
They may be used to calculate the primary parameters $\{Z_s, Y_p\}$ of the cable sections, per unit length.

NOTE: Conductance becomes significant at high frequencies and must not be ignored.

<FOR FURTHER STUDY>	[Ω/km] [S/km]

Table A.1 : 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.2

symbolic name							
“PE04”							
“PE05”							
“PE06”		<FOR	FURTHER	STUDY>			
“PE08”							
“PVC032”							
“PVC04”							
“PVC063”							

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

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 $\mathbf{R_V} = 135\ \Omega$.

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

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

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:

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

Annex B [informative]:
Rationale behind the noise models

The noise models of the individual NEXT-, FEXT-, background- and white-noise generators in the impairment generator, are based on the combined noise of different scenario's with xDSL 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. The three scenario's are based on a technology mix of SDSL interferers (self crosstalk) and non-SDSL interferers (alien crosstalk).

- ***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 (reference 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.

The power density of the individual interferers are evaluated, when terminated by R_V = 135Ω, the design impedance of HDSL, ISDN, VDSL.

- The PSD of the alien crosstalk sources {P_{XA}}, is the FSAN crosstalk sum [13] of {P_1, P_2, … P_n}. Combining this technology mix into a combined noise mask, and rounding its values, yields noise model XA.LT.A and XA.NT.A, as specified in table 5 and 6. Each noise model has identified an LT-PSD as well as an NT-PSD, to distinct upstream testing from downstream testing. The FSAN crosstalk sum for four individual PSD's equals (P in W/Hz):
  $P = (P_1^{Kn} + P_2^{Kn} + P_3^{Kn} + P_4^{Kn})^{1/Kn}$, at K_n=1/0.6
- The PSD of the self crosstalk sources {P_{XS}} (= P_0) is derived from the PSD of the SDSL system under teste. For complience with the requirements of the present document on SDSL, the transceiver manufacturer shall determine the signal spectrum of the SDSL system under test, at the highest bitrat, amplified by the specified 'gain factor' of the noise model.
- The PSD of the combined crosstalk sources of the noise model is the FSAN crosstalk sum [13] of {P_{XA}, P_{XS}}.

The inclusion in this mix of systems like ISDN-BA (4B3T) and HDSL (2-pair CAP) has also been considered. The large differences between the three noise models are assumed to be wide enough to cover these systems reasonably well. Their PSD's are included here for completeness, but are not used in the noise models.
Note that the "ADSL over ISDN" and "ISDN/2B1Q" systems may share the same wire pair, but contribute to the total PSD as individual systems.

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 10 and 11. The PSD masks in table 10 are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.

ISDN 2B1Q	***135 W***
[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 150W***
[Hz]	**[dBm/Hz]**
1	-30
50k	-30
300k	-67
301k	-74
1M	-74
4.043M	-120
30M	-120

HDSL 2B1Q	***2 pair 135 W***
[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 W***
[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

---

[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 over POTS DMT	*Up 100 W*
[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 W*
[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 W*
[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 W*
[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

ADSL-lite DMT	*Up 100 W*
[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 W*
[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 10: 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.

$$P(f) \;=\; \frac{2}{f_0} \cdot \frac{\mathrm{sinc}^2(f/f_0 - 1)}{1 + (f/f_{3dB})^{2 \cdot N}} \cdot P_0 \qquad [\mathrm{W/Hz}]$$

P_0 = 12.4 mW = 10.92 dBm; Rs=130 Ω;
f_0 = 1.024 MHz; f_{3dB} = 1.024 MHz; N=0.9
sinc(x) = sin($\pi \cdot x$) / ($\pi \cdot x$)

Table 11: PSD mask of the ISDN-PRI (HDB3) system, as function of the frequency.

The PSD levels, of the sources in table 10 and 11, 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 design 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 design 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 design 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 design impedance R_V=135Ω.

Annex C [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.
[2] **ETR 328:** "*Transmission and Multiplexing (TM); Asymmetric Digital Subscriber Line (**ADSL**); Requirements and performance*", ETSI, DTR/TM-06001, November 1996
[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.
[7] Rob F.M. van den Brink, Bas van den Heuvel, KPN, *Time domain requirements on noise in performance tests*, ETSI-TM6 contribution TD50 (985t50a0), Sophia Antipolis, Nov 1998.
[8] KPN/FSAN xDSL working group, *Revised noise models for SDSL*, ETSI-TM6 contribution TD20 (991t20a1), Villach, Austria, Feb 1999.
[9] KPN/FSAN xDSL working group, *Self-crosstalk update of the SDSL noise models*, ETSI-TM6 contribution TD9 (992t09a0), Grenoble, France, May 1999.
[10] KPN/FSAN xDSL working group, *Update of SDSL noise models, as requested by ETSI-TM6*, ETSI-TM6 contribution TD22 (993t22a0), Edinburgh, UK, Sept 1999.
[11] Marc Kimpe, ADTRAN, *Performance of TS 101 135 2-pair HDSL systems under various noise Models*, ETSI-TM6 contribution TD30 (985t27a0), Sophia Antipolis, Nov 1998.
[12] Thomas Kessler, DTAG, *Using FSAN noise models for SDSL*, ETSI-TM6 contribution TD49 (985t49a0), Sophia Antipolis, Nov 1998.
[13] FSAN xDSL working group, *Proposal for crosstalk combination method*, ETSI-TM6 contribution TD23 (985t23a0), Sophia Antipolis, Nov 1998.
[14] Rob F.M. van den Brink, KPN, *Compromise proposal for SDSL testloops,* ETSI-TM6 contribution TD23 (993t23a0), Edinburgh, Sept 1999.
[15] Rob van den Brink, KPN, "*Results of the ad hoc group on SDSL test loops*", ETSI-TM6 working document WD 19 (992w19xx) (formerly WD 18), Grenoble, May 1999
[16] Reinhard Stolle (Infineon), "*SDSL test loops*", ETSI-TM6 temporary document TD8 (993t08a0), Edinburgh, september 1999.
[17] Dirk Daecke (Infineon), "*Scaling of SDSL testloops for different bitrates*", ETSI-TM6 temporary document TD10 (993t10a2), Edinburgh, september 1999.