ETSI STC TM6

(ACCESS TRANSMISSION SYSTEMS ON METALLIC CABLES)

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Performance tests for SDSL 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 it is not excluded that this work becomes a basis for general performance tests on long range xDSL systems.
The main portion of this document is based on its original version [6] and updated with the time domain requirements described in [7] and the noise models described in [8].

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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 **R**$_V$ is 135Ω. All spectra are representing single sided power spectral densities (PSD’s).

1.1. 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.

1.1.1. 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 2.2;
- An adding element to add the impairment noise (a mix of random, impulsive and harmonic noise), as specified in sub-clause 2.3;
- 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.

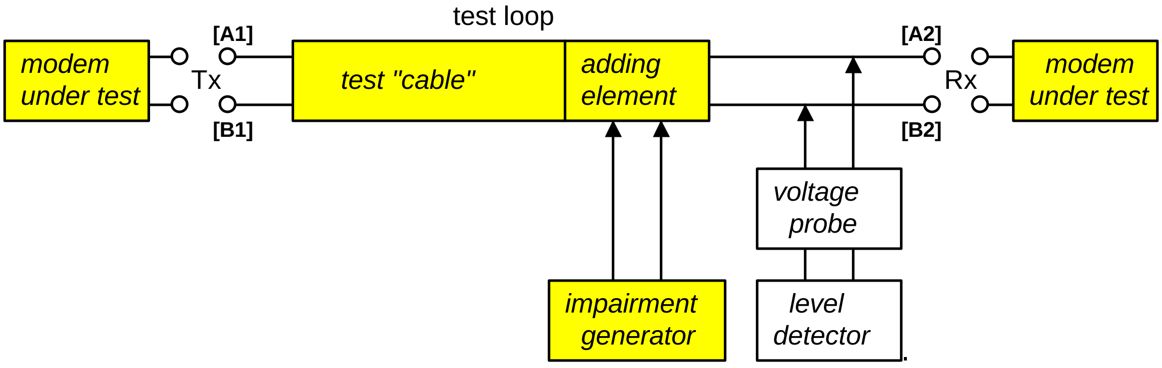


Figure 1: Functional description of the set-up of the performance tests. When external splitters are required for the xDSL system under test (for POTS or ISDN signals), this splitter shall be included in the modem under test.

The two-port characteristics (transfer function, impedance) of the test-loop, as specified in sub-clause 2.2, 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 2.2, shall always be used for calibrating and verifying the correct settings of generators G1-G7, as specified in sub-clause 2.3, 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 2.3. The level that is specified in sub-clause 2.3 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.

1.1.2. Startup training procedure

> 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

1.1.3. Signal and noise level definitions

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

1.2. Test loops

The purpose of the test loops shown in Figure 2 is to stress xDSL transceivers under test in various ways; in particular to test its performance under quasi realistic circumstances.

1.2.1. Functional description

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.

All other test loops in Figure 2 have equal *electrical* length (insertion loss at a specified test frequency), but differ in input impedance (see Figure 3). 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.

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 0,5 mm gauge 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.

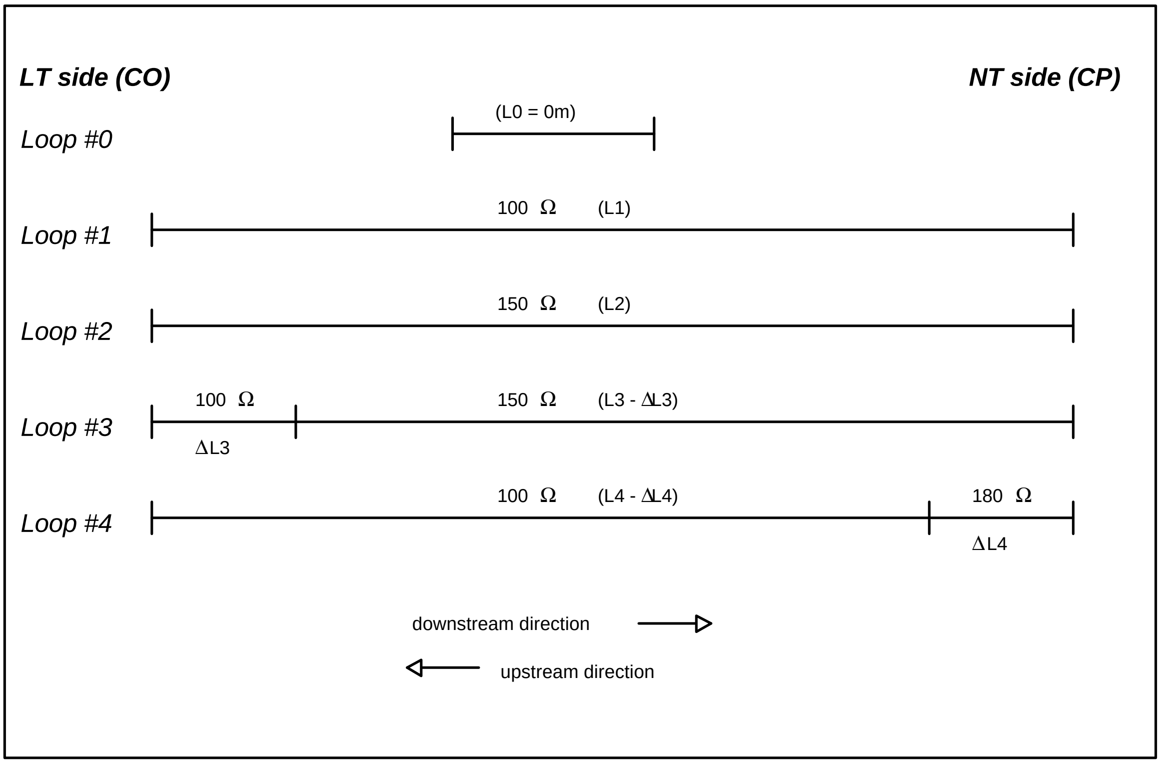


Figure 2: Test loop topology

Is their any need for SDSL to include an additional testloop with bridgetaps?
If this is not a European problem we can restrict ourselves to these four loops. Its a non-issue in the Dutch access network, so KPN has no need for it.

The higher the number of mismatches in the testloops, the higher the number of tabs shall be implemented in the echo cancellation

The variation of input impedance for the various test loops is shown in Figure 3. The transfer function of all the loops for each payload bit-rate is shown in Figure 4.

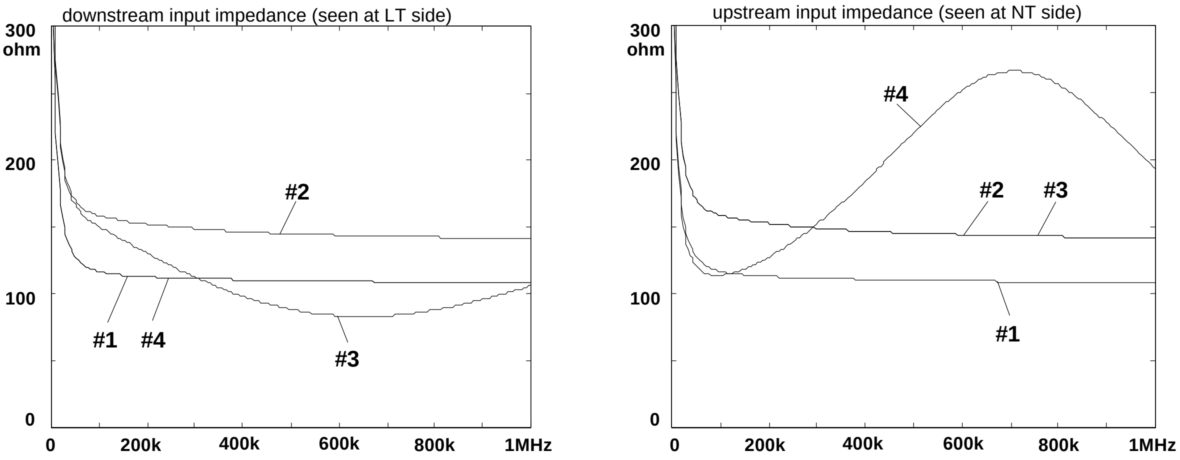


Figure 3: Calculated variation of input impedance (absolute value) of long testloops (≈6 km)

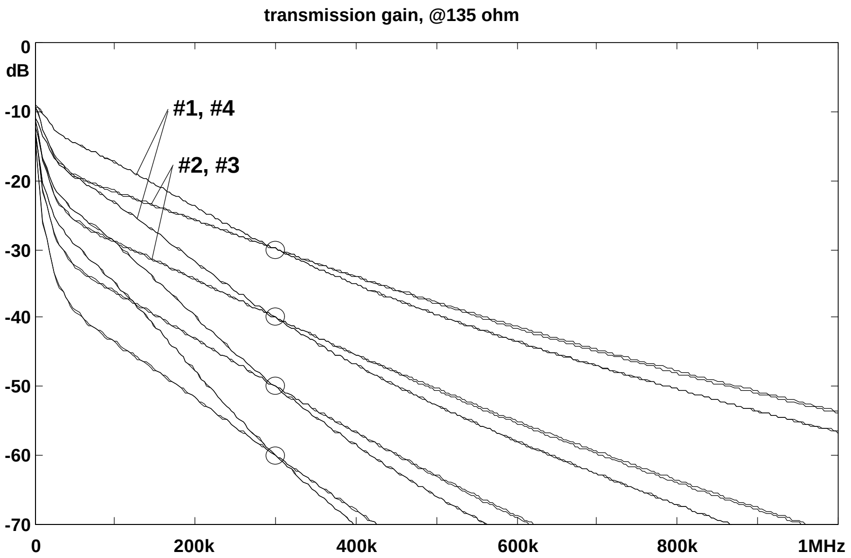


Figure 4: Transmission gain (in 135Ω) of the test-loops, for different electrical lengths (= insertion loss, @300kHz, @135Ω). Loop #1 and #4 are very similar in transmission gain; the same applies to loop #2 and #3, but their difference is small due to the normalization at 300 kHz.

The sections of the loops are defined in sub clause 2.2.2 by means of two-port cable models of the individual sections. Cable simulators as well as real cables can be used for these sections. To minimise the electrical differences between different testloop configurations, their “length” is specified as “electrical length” instead of the “physical length” of the sections in cascade (meaningful only when real cables are used). The electrical length is equivalent to the insertion loss of the loop at specified test frequency and resistance.

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. Several physical length approximations for a few insertion loss values are summarised in table 1.

Electrical length, (insertion loss in 135 Ω)	Physical length of loop #1 *(approximate)*	Physical length of loop #2 *(approximate)*	Physical length of loop #3 *(approximate)*	Physical length of loop #4 *(approximate)*
30 dB @ 300 kHz	2962.7 m	3033.8 m	3009.7 m	2979.4 m
40 dB @ 300 kHz	3952.2 m	4044.9 m	4020.9 m	3968.9 m
50 dB @ 300 kHz	4941.6 m	5056.1 m	5032.1 m	4958.4 m
60 dB @ 300 kHz	5931.1 m	6067.3 m	6043.2 m	5947.8 m

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

1.2.2. Loop topology requirements

The different cable sections in the topology of Figure 2 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 composition of sections in the test-loops is specified in Table 2. The associated models and line constants are specified in Annex A.

The testloop characteristics shall approximate the models within a specified accuracy:

- 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 3×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 f_T×3.

> How closely can a cable simulator meet the target specification for insertion loss, characteristic impedance, etc. Over what frequency band?
>
> Are the proposed accuracy numbers adequate?
>
> Accuracy limits are also required for the impedance phase and transmission group delay How critical is this group delay for modems (mean and ripple)?. Is 3% accuracy adequate and feasible?

Test loop	Distribution cable (L)	Extension cable (ΔL) LT or NT side	Extension length ΔL
#0	-	-	-
#1	"TP100"	-	-
#2	"TP150"	-	-
#3	"TP150"	"TP100x"	70 m
#4	"TP180"	"TP180x"	70 m

Table 2: Test-loop composition

NOTE: The labels "TPxxx" refer to the two-port cable models, specified in Annex A:

1.2.3. Electrical length requirements (insertion loss @ 300 kHz)

The electrical length of a testloop is defined as the insertion loss of that loop in R_V=135Ω, at f_T =300 kHz. This common impedance is chosen, because its the design impedance for input and output impedance of various xDSL transceivers (such as HDSL, VDSL, ISDN). This test frequency is chosen to be a typical high-band frequency in the spectrum of long range xDSL systems.

The electrical length, or insertion loss, is chosen as a typical maximum value that can be handled correctly by the xDSL transceiver under test. Its value can be bitrate dependent; the higher the payload bit-rate, the lower the insertion loss is that can be handled in practice. This is because the crosstalk in real cables increases with the frequency.

Table 3 specifies the electrical length for the different SDSL payload bit-rates.

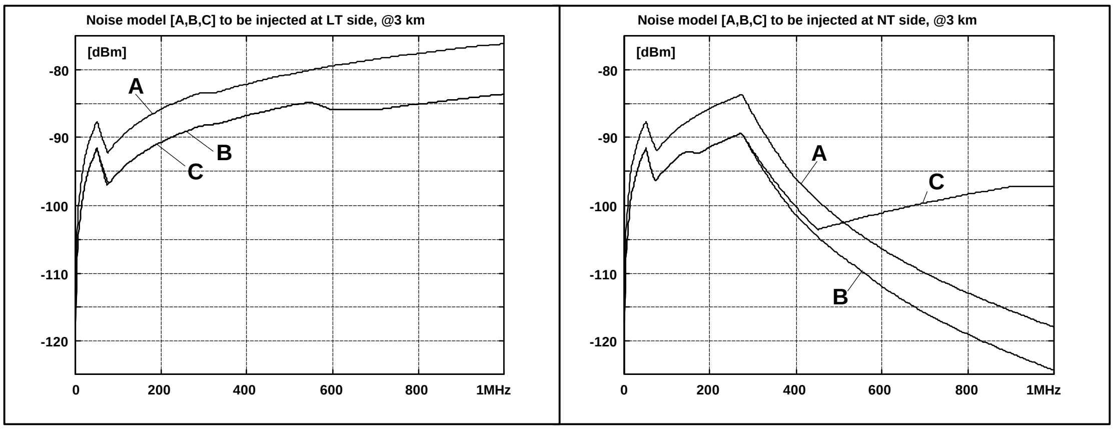
SDSL payload	Test frequency	Electrical length, or insertion loss	Calculated Physical length				
bit-rate	**f_T**	**@135Ω, @ f_T**	**avg**	**L1**	**L2**	**L3**	**L4**
TBD kb/s	300 kHz	TBD dB					
TBD kb/s	300 kHz	TBD dB					
TBD kb/s	300 kHz	TBD dB					
TBD kb/s	300 kHz	TBD dB					
TBD kb/s	300 kHz	TBD dB					
TBD kb/s	300 kHz	TBD dB					

Table 3 : Electrical length (insertion loss at specified test frequency and impedance) for loops #1 to #4, for various payload bit-rates

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

1.3. 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 three noise models 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 noise model 'B' is applied.


Noise model [A,B,C] to be injected at LT side, @3 km

Noise model [A,B,C] to be injected at NT side, @3 km

Figure 5: Example of noise spectra that are to be injected into the test setup, while testing SDSL systems. Its the noise, resulting from the three noise models for SDSL, in the case that the length of testloop #1 is fixed at 3 km.

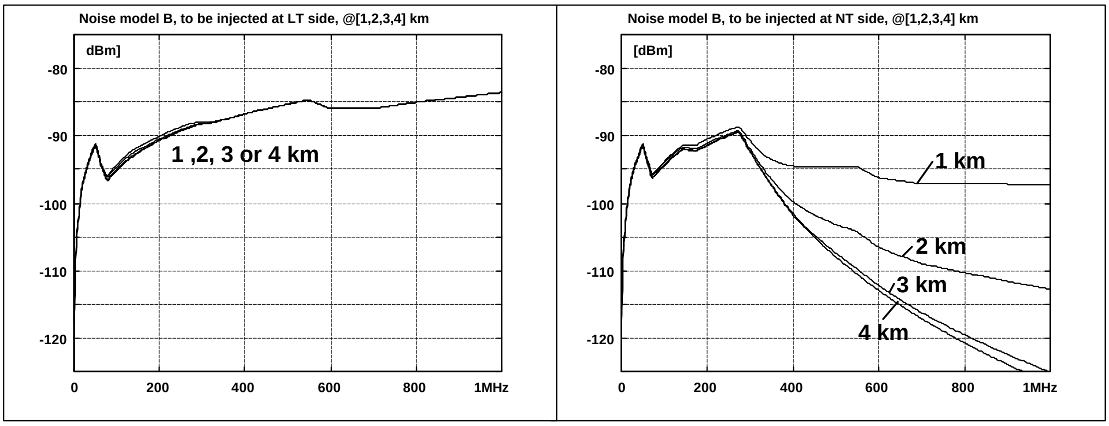


Figure 6: Example of noise spectra that are to be injected into the test setup, while testing SDSL systems. Its the noise, resulting from noise model B for SDSL, in the case that the length of testloop #1 varies from 1km to 4 km. This demonstrates that the noise is length dependent, to represent the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

1.3.1. Functional description

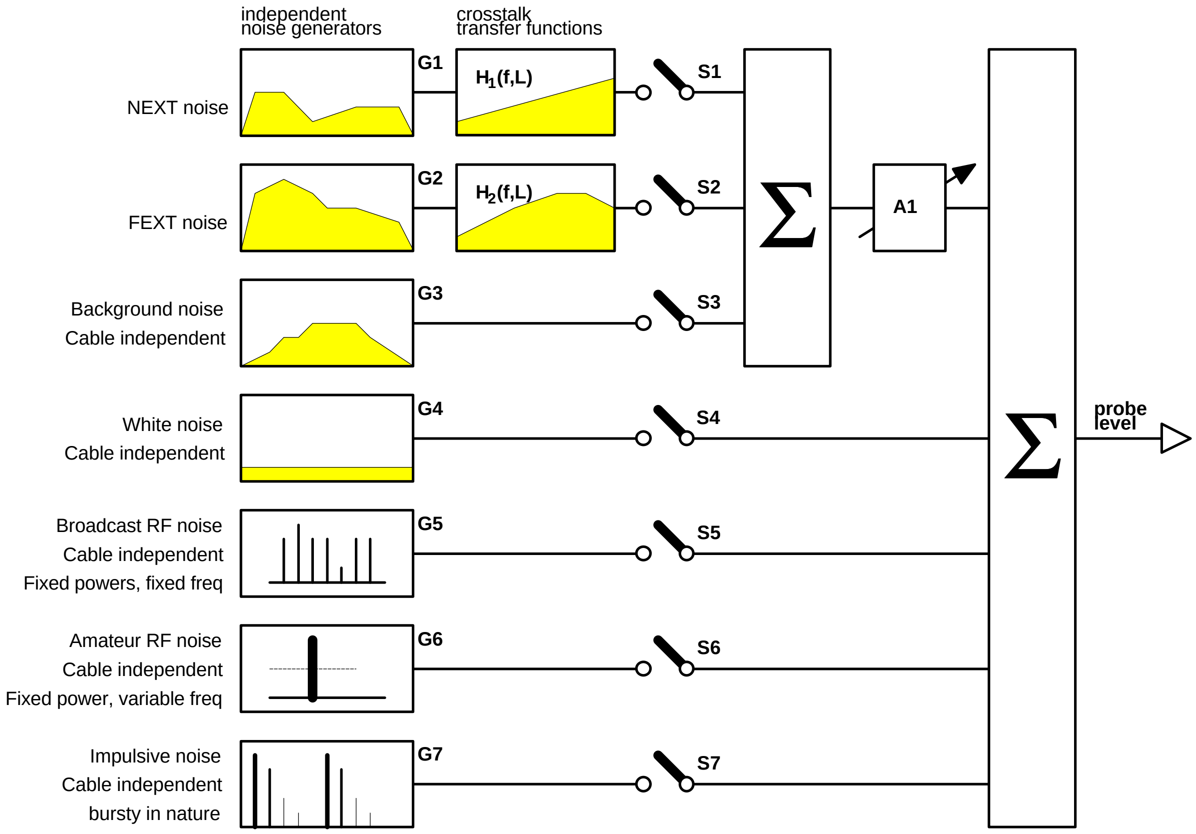
Figure 7 defines a functional diagram of the composite impairment noise. It defines a functional description of the combined impairment noise, as it must be probed at the receiver input of the xDSL transceiver under test. This probing is defined in sub-clause 2.1.3.

The functional diagram has the following elements:

- The seven impairment "generators" G1 to G7 generate noise as defined in sub-clause 2.3.5 to 2.3.11. 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 2.3.2. 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 2.3.2. 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 2.4.2. 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. Three 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 results in a length dependent PSD description of noise models. Each 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 impairment "sources" 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".

Each test has its own impairment specification, as specified in sub clause 2.4. 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.

1.3.2. 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 $\mathbf{f_0}$ identifies a chosen reference frequency, which was set to 1 MHz.
- Variable **L** identifies an average physical length in meters, averaged over the four test loops at specified payload bit-rate. The average physical length is defined as $\mathbf{L}=(L_1+L_2+L_3+L_4)/4$, where $L_1..L_4$ represent the calculated physical test-loop lengths according to Table 3, in the case that real cables are used.
- Constant $\mathbf{L_0}$ identifies a chosen reference length, which was set to 1 km.
- Transfer function $\mathbf{s_{T0}(f, L)}$ represents an average transfer function of the four test-loops at specified payload bit-rate. Its transfer function is independent of the loop-set number, but changes with the specified electrical length. Since all loops have the same electrical length (normalised in insertion loss), the transfer function of test loop #1 is chosen to "represent" this average.
- Constant $\mathbf{K_{xn}}$ 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 $\mathbf{K_{xf}}$ 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 4 shall be used as cross-talk transfer functions in the impairment generator.

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

Table 4 : 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.

It is very important that information becomes available on crosstalk figures in cables of several European operators. Without this information, it remains unclear how representative the total impairment noise is in this performance tests.

1.3.3. Frequency domain profiles of crosstalk noise sources

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, and therefore it is defined as the powersum of noise, generated by four individual noise sources: G1, G2, G3 and G4.

- The PSD of NEXT source G1 equals one of the combined crosstalk noise models, as specified in this sub-clause 2.3.3. The LT-PSD of that noise model shall be used for upstream testing and the NT-PSD for downstream testing. This spectral profile, filtered by the NEXT crosstalk coupling function of sub-clause 2.3.2, will represent its contribution to the overall crosstalk noise.
- The PSD of FEXT source G2 equals one of the combined crosstalk noise models, as specified in this sub-clause 2.3.3. The NT-PSD of that noise model shall be used for upstream testing and the LT-PSD for downstream testing. This spectral profile, filtered by the FEXT crosstalk coupling function of sub-clause 2.3.2, will represent its contribution to the overall crosstalk noise.
- The PSD of source G3 is set to zero.
- The PSD of source G4 is white and set to –140dBm/Hz, to represent background noise.

1.3.3.1. PSD profiles of self crosstalk sources

The noise profile of self crosstalk is implementation specific of the xDSL system under test, and may also be test loop specific. 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 described in sub clause 2.1.1. The measurement bandwidth for PSD shall be 1 kHz. or less.

For SDSL, three noise noise models for self crosstalk have been defined, and for each noise model, two spectral profiles are identified:

- The models XS.LT.# are intended to be applied at the LT end of the test loop, for stressing upstream signals. The alien LT-models are specified in table 5.
- The models XS.NT.# are intended to be applied at the NT end of the test loop, for stressing downstream signals. The alien NT-models are specified in table 5.

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

	Model A (XS.#.A)	**Model B** (XS.#.B)	**Model C** (XS.#.C)
XS.LT.#:	“SDSL.dn” + **TBD** dB	“SDSL.dn” + **TBD** dB	“SDSL.dn” + **TBD** dB
XS.NT.#:	“SDSL.up” + **TBD** dB	“SDSL.up” + **TBD** dB	“SDSL.up” + **TBD** dB

Table 5: Definition of the self crosstalk. The different noise models use different Gain factors.

ED. As long as these numbers on self crosstalk remains undefined, KPN proposes to add 11.7 dB to evaluate model A, 7.8 dB to evaluate model B, and 7.8 dB to evaluate model C. This represents 90, 20, 20 SDSL systems repectively, which is in line with the current assumptions on the three noise models.

1.3.3.2. PSD profiles of alien crosstalk sources.

For SDSL, three noise noise models for alien crosstalk have been defined, and for each noise model, two spectral profiles are identified:

- The models XA.LT.# are intended to be applied at the LT end of the test loop, for stressing upstream signals. The alien LT-models are specified in table 6.
- The models XA.NT.# are intended to be applied at the LT end of the test loop, for stressing downstream transmission. The alien NT-models are specified in table 7.

In this nomenclature is “#” a placeholder for model “A”, “B” or “C”. The rationals behind these models are described in annex C.

XA.LT.A [Hz]	***135 W*** [dBm/Hz]
1	–18.2
50 k	–18.2
75 k	–25.4
290 k	–25.4
330 k	–26.1
1104 k	–26.1
2.50 M	–66.2
4.53 M	–96.5
30 M	–96.5

XA.LT.B [Hz]	***135 W*** [dBm/Hz]
1	–22.2
50 k	–22.2
77 k	–30.2
292 k	–30.3
330 k	–30.8
550 k	–30.8
600 k	–32.6
700 k	–33.6
1104 k	–33.6
4.53 M	–101
30 M	–101

XA.LT.C [Hz]	***135 W*** [dBm/Hz]
1	–22.2
50 k	–22.2
74 k	–30.2
292 k	–30.3
330 k	–30.8
550 k	–30.8
600 k	–32.6
700 k	–33.6
1104 k	–33.6
2 M	–62
15 M	–101
30 M	–101

Table 6: Break frequencies of the “XA.LT.#” PSD masks that specify noise spectra as used in sub-clause 2.3.5 and 2.3.6. The PSD masks 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 W*** [dBm/Hz]
1	–18.2
50 k	–18.2
75 k	–25.2
275 k	–25.3
400 k	–40.5
600 k	–54.3
1 M	–71.5
2.75 M	–96.5
30 M	–96.5

XA.NT.B [Hz]	***135 W*** [dBm/Hz]
1	–22.2
50 k	–22.2
71 k	–29.3
145 k	–29.5
175 k	–31.0
274 k	–31.0
400 k	–45.9
600 k	–59.6
1 M	–76.8
2 M	–93.5
3 M	–101
30 M	–101

XA.NT.C [Hz]	***135 W*** [dBm/Hz]
1	–22.2
50 k	–22.2
71 k	–29.3
145 k	–29.5
175 k	–31.0
274 k	–31.0
450 k	–48.8
900 k	–46.6
1.2 M	–48.2
1.5 M	–52.0
1.78 M	–60.3
16 M	–101
30 M	–101

Table 7: Break frequencies of the “XA.NT.#” PSD masks that specify the alien noise spectra as used in sub-clause 2.3.5 and 2.3.6. The PSD masks 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.

1.3.4. Time domain profiles on crosstalk noise sources

The noise, as specified in the frequency domain in sub-clause 2.3.5 to 2.3.8, 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 8.

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).

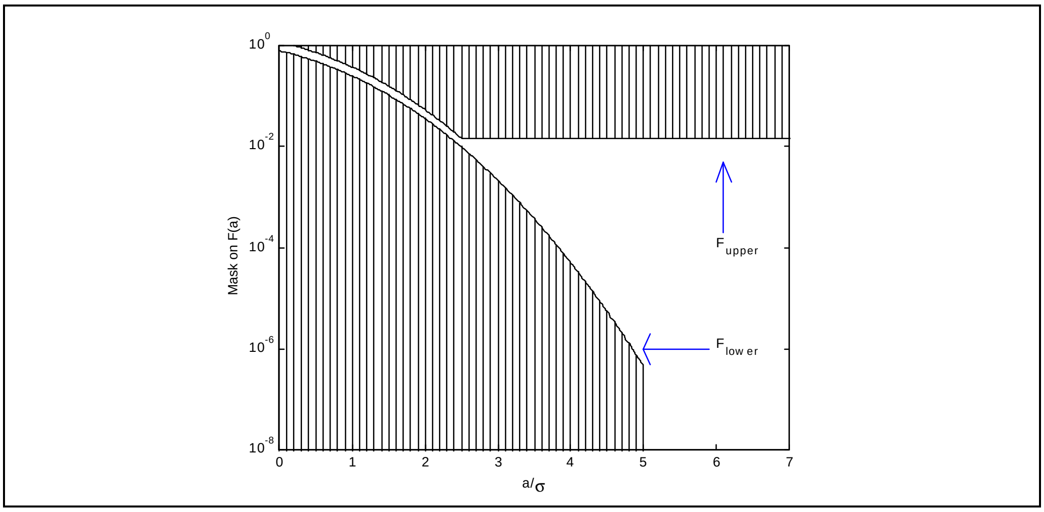


Figure 8: Mask for the Amplitude Distribution Function: the non-shaded area is the allowed region. The boundaries of the mask are specified in Table 8.

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

The meaning of the parameters in table 8 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

1.3.5. NEXT noise models [G1.xx]

The NEXT noise generator represents all impairment that is identified as crosstalk noise from a predominantly Near End origin.

This 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 2.3.4.

The PSD of this noise generator is a combination of the self crosstalk source and the alien crosstalk source. 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” or “C”.
- Symbol “XS.LT.#” and “XS.NT.#” refers to self crosstalk noise, as defined in sub-clause 2.3.3.1
- Symbol “XA.LT.#” and “XA.NT.#” refers to alien crosstalk noise, as defined in sub-clause 2.3.3.2
- 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 2.3.2.

1.3.6. FEXT noise models [G2.xx]

The FEXT noise generator represents all impairment that is identified as crosstalk noise from a predominantly Far End origin.

This 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 2.3.4.

The PSD of this noise generator is a combination of the self crosstalk source and the alien crosstalk source. 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” or “C”.
- Symbol “XS.LT.#” and “XS.NT.#” refers to self crosstalk noise, as defined in sub-clause 2.3.3.1
- Symbol “XA.LT.#” and “XA.NT.#” refers to alien crosstalk noise, as defined in sub-clause 2.3.3.2
- 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 2.3.2.

1.3.7. Background noise model [G3]

The background noise generator is Inactive and set to zero.

1.3.8. White noise model [G4]

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

1.3.9. Broadcast RF noise model [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.

1.3.10. Amateur RF noise model [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, whioch is far above the SDSL frequency band.

1.3.11. Impulse noise model [G7]

A test with this noise model 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 2.4.

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

1.4. Transmission Performance tests

1.4.1. 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 2.4.3 and 2.4.4).

1.4.2. 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 2.3. This relative level is referred to as 0 dB. The transceiver link is subsequently activated, and the bit error ratio of the link is monitored.

1.4.2.1. 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 **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.

1.4.2.2. Measuring impulse noise margin

Ed. This whole issue is subject for further study

1.4.3. Upstream tests

Several xDSL performance tests shall be carried out to prove adequate upstream 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 2.3. 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		0-4	G1.LT.A	G2.LT.A	G3	-	G5	-	-
U2		4	-	-	-	-	-	-	G7

Table 9: Test matrix with composition of noise models in the upstream tests

1.4.4. Downstream tests

Several xDSL performance tests shall be carried out to prove adequate downstream performance. These tests are specified in Table 10. Each symbolic name in this table refers to a specified noise model as defined in sub-clause 2.3. 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		0-4	G1.NT.A	G2.NT.A	G3	-	G5	-	-
D2		4	-	-	-	-	-	-	G7
									-
									-
									-

Table 10: Test matrix with composition of noise models in the Downstream tests

1.5. 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 30 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.

Ed. This appendix needs a layout update, but the content is correct.

BT#0	$Z_s(f) = \sqrt[4]{R_{oc}{}^4 + a_c \cdot f^2} + j \cdot 2\pi f \cdot \left(\dfrac{L_0 + L_\infty \cdot (f / f_m)^{Nb}}{1 + (f / f_m)^{Nb}} \right)$ $Y_p(f) = (g_0 \cdot f^{\,Nge}) + j \cdot 2\pi f \cdot (C_\infty + C_0 / f^{\,Nce})$	$[\Omega/\mathrm{km}]$ $[\mathrm{S/km}]$
KPN#1	$Z_{s0}(\omega) = j \cdot \omega \cdot Z_{0\infty} \cdot 1/c + R_{ss00} \cdot (1 + K_l \cdot K_f \cdot (\chi \cdot \coth(4/3 \cdot \chi) - 3/4))$ $Y_{p0}(\omega) = j \cdot \omega / Z_{0\infty} \cdot 1/c \cdot (1 + (K_c - 1) / (1 + (\omega/\omega_{c0})^N)) + \tan(\phi)/(Z_{0\infty} \cdot c) \cdot \omega^M$ $\chi = \chi(\omega) = (1+j) \cdot \sqrt{\dfrac{\omega}{2\pi} \cdot \dfrac{\mu_0}{R_{ss00}} \cdot \dfrac{1}{K_n \cdot K_f}}\,,$ $\omega_{c0} = 2\pi \cdot f_{c0}, \quad \mu_0 = 4 \cdot \pi \cdot 10^{-7}\ [\mathrm{H/m}], \quad c_0 = 3 \cdot 10^8\ [\mathrm{m/s}]$	$[\Omega/\mathrm{m}]$ $[\mathrm{S/m}]$

Table A.1 : The BT and KPN 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 and Table A.3.
Both models are equally valid from DC to 30 MHz when using the appropriate parameter sets and values. Note that the BT model is specified in kilometers, and the KPN model in meters.

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

Table A.2 : 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.3 : Line constants for the TP150 and TP100x cable sections in the test loops, that are defined by the KPN#1 model.

Insertion loss and return loss at $\mathbf{R_V} = 135\ \Omega$ can be calculated from $\{Z_s, Y_p\}$ by evaluating the two-port s-parameters, normalized to $\mathbf{R_V}$**,** according to

Scaling the primary parameters (per unit length) to their actual length is:
(L_0 = 1km in the BT model, and L_0 = 1m in the KPN model

$$Z_{sx} = (L/L_0) \cdot Z_s$$
$$Y_{sx} = (L/L_0) \cdot Y_s$$

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

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

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

	Frequency (Hz)	**Resistance (Ω/km)** R_{sx}	**Inductance (H/km)** L_{sx}	**Capacitance (F/km)** C_{px}	**Conductance (S/km)** G_{px}	**Insertion loss (dB) @ 1km @ 135Ω**	**Characteristic impedance (Ω)** Z_0
TP100	1 k	179.00	694.972e-6	55.501e-9	0.0006e-3	4.42	716.56
	10 k	179.16	694.564e-6	55.398e-9	0.0068e-3	4.57	230.16
	100 k	192.93	688.471e-6	55.316e-9	0.0731e-3	7.30	116.74
	1 M	438.33	640.000e-6	55.251e-9	0.7888e-3	18.13	107.94
	10 M	1376.49	591.529e-6	55.200e-9	8.5108e-3	61.72	103.55
TP150	1 k	168.15	784.381e-6	33.099e-9	0.0040e-3	4.21	899.29
	10 k	168.47	784.199e-6	33.072e-9	0.0401e-3	4.26	290.62
	100 k	197.37	768.161e-6	32.942e-9	0.4011e-3	5.77	158.71
	1 M	527.25	645.503e-6	32.454e-9	4.0107e-3	18.66	141.61
	10 M	1539.30	594.606e-6	31.501e-9	40.1067e-3	72.59	137.43
TP100x	1 k						
	10 k						
	100 k						
	1 M						
	10 M						
TP180x	1 k	41.16	999.814e-6	37.456e-9	0.0231e-3	1.25	419.63
	10 k	41.59	997.166e-6	34.128e-9	0.1755e-3	1.37	186.96
	100 k	62.28	969.667e-6	31.549e-9	1.3313e-3	2.65	175.57
	1 M	186.92	920.407e-6	29.551e-9	10.0989e-3	12.50	176.40
	10 M	590.76	911.210e-6	28.003e-9	76.6083e-3	74.41	180.31

Table 11*: Simulation results, computed from the models*

Annex B [informative]: Cable information

The following material, though not specifically referenced in the body of the TS, gives supporting information regarding cable construction.
The cable sections in the testloops are representative of existing European metallic access cables. They represent the following cables, as described in more detail in [1].

Cable type TP100 (equivalent to the BT_dwug cable in [1])
Multiple pair. 0.5 mm solid copper conductors. Polyethylene insulated. Predominantly used for underground distribution.

Cable type TP150 (equivalent to the KPN_L1 distribution cable in [1])
Multiple quads (4 wires or two pairs), 0.5mm solid copper conductors. Paper insulation. The cables are constructed in concentric layers, and each layer consists of a number of twisted quads. The bundle of quads is mechanically protected by a shield of lead that is grounded to earth. Predominantly used for underground distribution.
This class covers cables up to 900 wire pairs (=450 quads) in the same bundle, organized as 450 quads in 11 concentric layers (no binder groups). A 50 quad version has been used as template for modelling.

Cable type TP100x (equivalent to the KPN_R2 indoor cable in [1])
Four twisted pairs, 0.5mm solid copper conductors, shielded by a foil. Category 5 LAN cable. Used in Dutch local exchanges as indoor cable, to connect xDSL equipment with distribution cable (Polyethylene insulated).

Cable type TP180x (equivalent to the BT_dw8 cable in [1])
Single pair dropwire. Flat twin (i.e. untwisted). 1.14 mm cadmium copper conductors. PVC insulated. No steel strength member.

Annex C [informative]:
Rationals 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 in model A (high penetration)***

P_0	SDSL	+ **TBD** dB (occupying about **TBD** 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 in model B (medium penetration)***

P_0	SDSL	+ **TBD** dB (occupying about **TBD** wire pairs)
P_1	ISDN/2B1Q	+ 7.8 dB (occupying about 20 wire pairs)
P_2	HDSL/2B1Q (2-pair)	+ 4.2 dB (occupying about 5 wire pairs)
P_3	ADSL-lite	+ 7.8 dB (occupying about 20 wire pairs)
P_4	ADSL over ISDN	+ 6.0 dB (occupying about 10 wire pairs)

- ***Technology mix in model C (legacy)***

P_0	SDSL	+ **TBD** dB (occupying about **TBD** wire pairs)
P_1	ISDN/2B1Q	+ 7.8 dB (occupying about 20 wire pairs)
P_2	HDSL/2B1Q (2-pair)	+ 4.2 dB (occupying about 5 wire pairs)
P_3	ADSL-lite	+ 7.8 dB (occupying about 20 wire pairs)
P_4	ADSL over ISDN	+ 6.0 dB (occupying about 10 wire pairs)
P_5	ISDN-PRI/HDB3	+ 3.6 dB (occupying about 4 wire pairs)

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

- The PSD of the alien crosstalk sources {P_{XA}}, is the FSAN crosstalk sum [11] of {P_1, P_2, … P_n}. The resulting PSD's are specified in table 6 and 7. Each noise model has identified an LT-PSD as well as an NT-PSD, to distinct upstream testing from downstream testing.
- The PSD of the self crosstalk sources {P_{XS}} (= P_0) is derived from the PSD of the SDSL system under test. 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, 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 [11] 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 12 and 13. The PSD masks in table 12 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	-30
50k	-30
300k	-69
301k	-79
500k	-90
1.4M	-90
3.637M	-120
30M	-120

ISDN 4B3T	***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	-39
292k	-39
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

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 12: 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
$\mathrm{sinc}(x) = \sin(\pi \cdot x) / (\pi \cdot x)$

Table 13: PSD mask of the ISDN-PRI (HDB3) system, as function of the frequency.

The PSD levels, of the sources in table 12 and 13, 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.

C.1. Composition of alien noise model A

Technology mix:

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

Crosstalk combination of individual PSD's (in W/Hz):
$P = (P_1^{Kn} + P_2^{Kn} + P_3^{Kn} + P_4^{Kn})^{1/Kn}$, at K_n=1/0.6

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 6 and 7. It is the rounded envelope of the calculated combined PSD.

C.2 Composition of alien noise model B

Technology mix:

P_1	ISDN/2B1Q	+ 7.8 dB (occupying about 20 wire pairs)
P_2	HDSL/2B1Q (2-pair)	+ 4.2 dB (occupying about 5 wire pairs)
P_3	ADSL-lite	+ 7.8 dB (occupying about 20 wire pairs)
P_4	ADSL over ISDN	+ 6.0 dB (occupying about 10 wire pairs)

Crosstalk combination of individual PSD's (in W/Hz):
$P = (P_1^{Kn} + P_2^{Kn} + P_3^{Kn} + P_4^{Kn})^{1/Kn}$, at K_n=1/0.6

Combining this technology mix into a combined noise mask, and rounding its values, yields noise model XA.LT.B and XA.NT.B, as specified in table 6 and 7. It is the rounded envelope of the calculated combined PSD.

C.3 Composition of alien noise model C

Technology mix:

P_1	ISDN/2B1Q	+ 7.8 dB (occupying about 20 wire pairs)
P_2	HDSL/2B1Q (2-pair)	+ 4.2 dB (occupying about 5 wire pairs)
P_3	ADSL-lite	+ 7.8 dB (occupying about 20 wire pairs)
P_4	ADSL over ISDN	+ 6.0 dB (occupying about 10 wire pairs)
P_5	ISDN-PRI/HDB3	+ 3.6 dB (occupying about 4 wire pairs)

Crosstalk combination of individual PSD's (in W/Hz):
$P = (P_1^{Kn} + P_2^{Kn} + P_3^{Kn} + P_4^{Kn} + P_5^{Kn})^{1/Kn}$, at K_n=1/0.6

Combining this technology mix into a combined noise mask, and rounding its values, yields noise model XA.LT.C and XA.NT.C, as specified in table 6 and 7. It is the rounded envelope of the calculated combined PSD.

Annex D [informative]: References

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