
TITLE **Proposal for SDSL performance tests**

PROJECT SDSL, and also ADSL over ISDN

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STATUS Proposal

ABSTRACT This contribution is a detailed proposal for testloops, noise models and test requirements on SDSL. The framework of this text is mainly based on the VDSL performance tests, but dedicated to the SDSL frequency band. It enables well-defined performance simulations on SDSL to support the future definition of realistic SDSL requirements such as spectral masks, bitrates, loop length etc.

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1. Problem description

At the Luleå meeting, it was agreed to give priority to performance tests (test loops, and noise models) for SDSL. These models must be available directly from the start of the SDSL definition phase, to enable comparison of various proposals on modulation schemes and frequency band allocation by means of performance simulations. This is a first but very detailed proposal.

SDSL
The approach of these test have been taken from the VDSL performance tests, but down scaled to SDSL frequencies.
It is believed that most (or all) of its content is not controversial, and that only unsolved issues are left.
If true, then ETSI-TM6 has made a major step forward in defining the SDSL functional requirements.
It enables ETSI-TM6 to specify these requirements on performance simulations from SDSL manufacturers that are based on realistic assumptions on operational access networks.

ADSL
Although this proposal is primarily written for SDSL, its also an excellent basis for generic performance tests on all long range xDSL systems. About 99% of this proposal is directly applicable to the ADSL over ISDN project, in order to redefine the ADSL performance tests for European access networks. Using these test, will improve the applicability of the test results, because they are a closer description of what will happen in real operational networks that become very noisy by the time mass deployment of ADSL systems is common procedure. The current ADSL performance tests are too optimistic and therefore of very limited value.

2. Transmission performance tests on SDSL

The purpose of transmission performance tests is to stress SDSL transceivers in a way that is representative to a worst case scenario in operational access networks, that is supposed to cover roughly 99% of the cases. This worst case 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, SDSL may perform better than tested
The performance requirements given in this clause shall be met by SDSL transceivers. The design impedance $\mathbf{R}_V$ is 135Ω.
All spectra are representing single sided power spectral densities (PSD’s).

2.1. 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 SDSL signals 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.

2.1.1. 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 SDSL band) differential voltage probe connected with level detectors such as a spectrum analyser or a true rms volt meter.

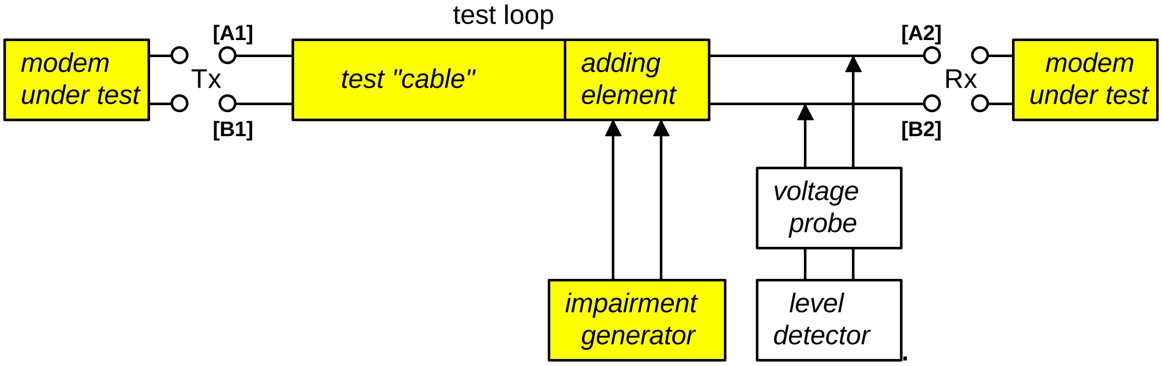


Figure 1: Functional description of the set-up of the performance tests. When external splitters are required for SDSL over POTS or ISDN, this splitter shall be included in the modem under test.

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 SDSL 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.

2.1.2. 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 SDSL 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.

2.2. Test loops

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

2.2.1. Functional description

Loop #0 is a symbolic name for a loop with zero (or near zero) length, to prove that the SDSL transceiver 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.

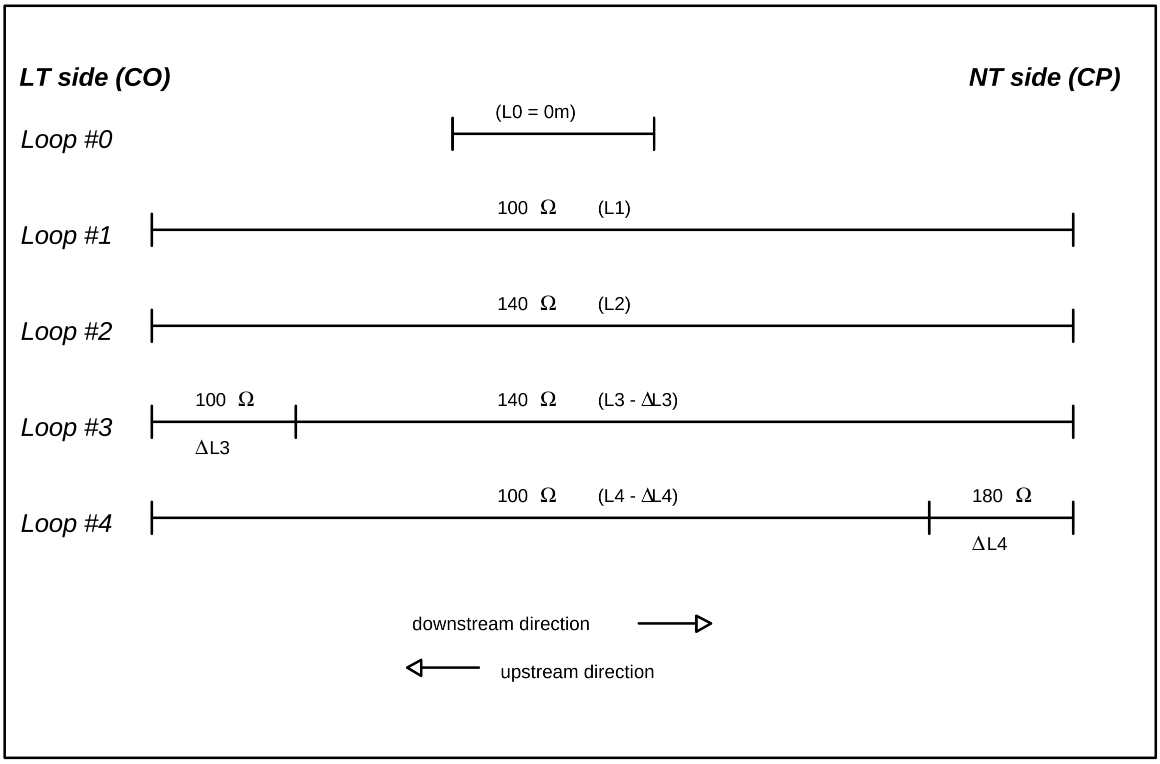


Figure 2: Test loop topology

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 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.

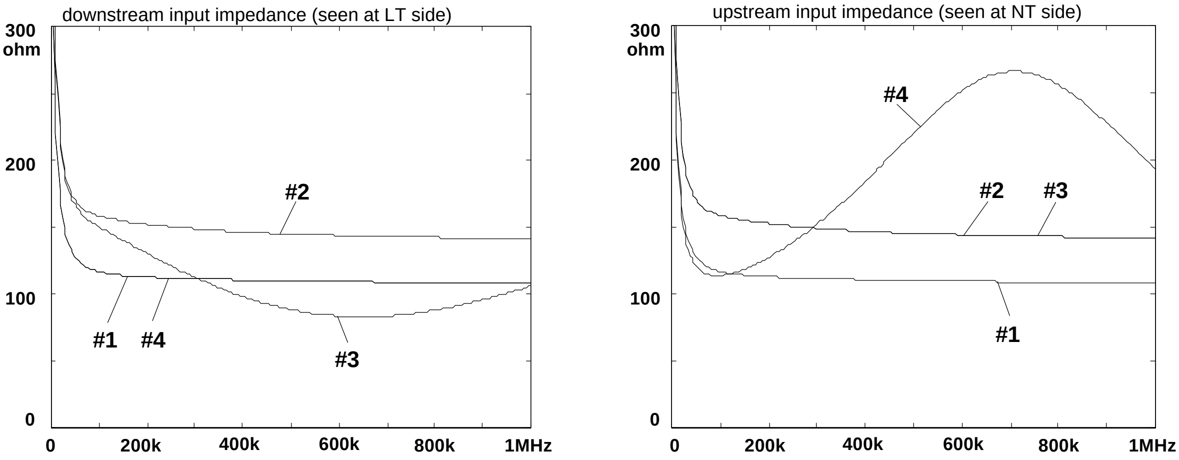


Figure 3: Calculated variation of input impedance (absolute value) of long testloops (≈6 km)

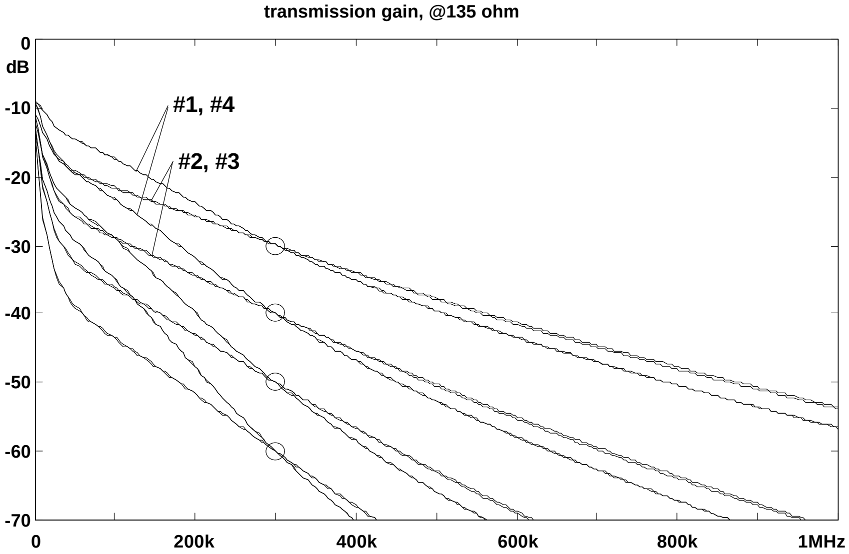


Figure 4: Transmission gain (in 135Ω) of the test-loops, for different electrical lengths (= insertion loss, @300kHz, @135Ω). Loop #1 and #4 are very similar in transmission gain; the same applies to loop #2 and #3, but their difference is small due to the normalization at 300 kHz.

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.

2.2.2. 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 $0,1 \times f_T$ and $3 \times f_T$.
- The magnitude of the test-loop characteristic impedance shall approximate the characteristic impedance of the specified models within 7% on a linear scale, between $0,1 \times f_T$ and $f_T \times 3$.

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	“BT_dwug ”	-	-
#2	“KPN_L1”	-	-
#3	“KPN_L1”	“KPN_R2”	70 m
#4	“BT_dwug”	“BT_dw8”	70 m

Table 2: Test-loop composition

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

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

The electrical length of an SDSL testloop is defined as the insertion loss of that loop in R_V=135Ω, at f_T =300 kHz. This common impedance is chosen to be the design impedance for input and output impedance of SDSL transceivers. This test frequency is chosen to be a typical high-band frequency in the SDSL spectrum.

The electrical length, or insertion loss, is chosen as a typical maximum value that can be handled correctly by the SDSL transceiver. 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 bit-rate	Test frequency f_T	Electrical length, or insertion loss @135Ω, @ f_T	Calculated Physical length				
			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.

2.3. Impairment generator

The impairment noise for SDSL 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 SDSL. The detailed specifications for the components of the noise model(s) are given in this sub-clause, together with a brief explanation.

2.3.1. Functional description

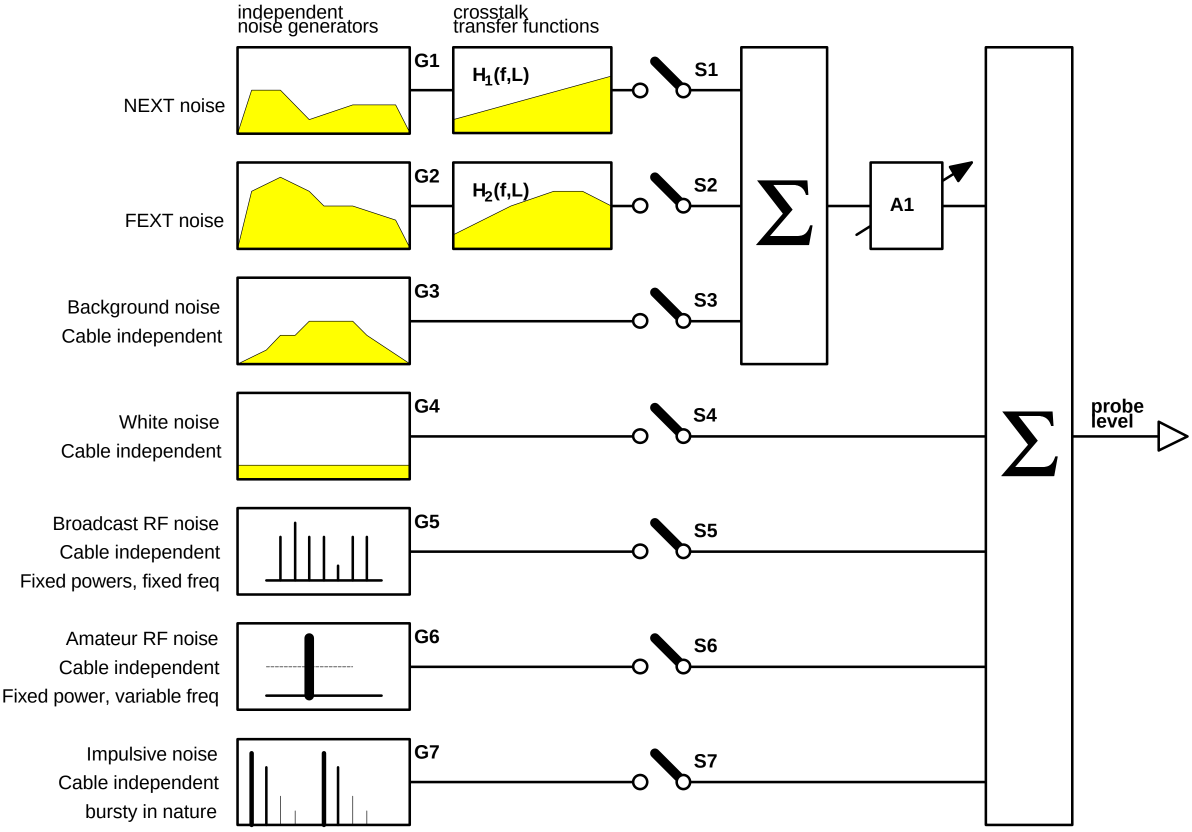
Figure 5 defines a functional diagram of the composite impairment noise. It defines a functional description of the combined impairment noise, as it must be probed at the receiver input of an SDSL transceiver under test. This probing is defined in sub-clause 2.1.2.

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 SDSL band, 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 5. 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 5: Functional diagram of the composition of the impairment noise

This functional diagram will be used for impairment tests in downstream and upstream direction. Some of the seven impairment "generators" G1 to G7 are therefore defined by more than one noise model. Each model is dedicated to a performance test, as specified in sub-clause 2.4. These models are intended to be representative of the impairments found in metallic access networks.

NOTE: **Type "A" models** are intended to represent a worse case situation where SDSL is placed in a distribution cable (up to hundreds of wire pairs) that is filled with many other (incompatible) transmission systems. The test noise represents the crosstalk noise from the technology mix: ISDN-BA (2B1Q), two-pair HDSL (2B1Q), ADSL over ISDN (DMT) and SDSL. The type "LT.A" models are intended to be applied at the LT end of the test loops to stress the upstream transmission. The type "NT.A" models are intended to be applied at the NT end of the test loops to stress the downstream transmission.

Type "B" models ????

is there any need for another technology mix, that is significantly different?

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.

2.3.2. 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 5 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.

$$H_1(f, L) = K_{xn} \times (f/f_0)^{0.75} \times \sqrt{1 - |s_{T0}(f, L)|^4}$$

$$H_2(f, L) = K_{xf} \times (f/f_0) \times \sqrt{(L/L_0)} \times |s_{T0}(f, L)|$$

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

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

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

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 adequate the noise models in this performance tests are.

2.3.3. 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.

Issues like crestfactor (between 5 and 8?), maximum repetition rate (when pseudo random noise is generated), and cumulated probability density, are topics for further study

2.3.4. 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 SDSL system under test. The PSD of noise generator G1 and G2 is a function of PSD profiles only due to a given worst case assumption of transmission system mix in a multi-pair cable. Its a composition of self-crosstalk originating from similar SDSL systems, and (self-crosstalk) and from other systems.
This sub-clause specifies the individual components of the crosstalk noise generators. The resulting PSD's, are specified in sub-clause clause 2.3.5 to 2.3.6.

2.3.4.1. Self crosstalk PSD profiles

The noise profile of self crosstalk is SDSL implementation specific, and may 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 SDSL 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.
Two spectral profiles are identified, one for upstream and another for downstream transmission.

XS.up: is an upstream PSD that is 10 dB above the signal spectrum that the SDSL transceiver under test transmits in upstream direction, into the NT side of the access network cable. This spectral profile, filtered by the two crosstalk coupling functions of sub-clause 2.3.2, will simulate the self-NEXT and self-FEXT for upstream transmission, generated by a high volume (in the order of tens) of similar SDSL systems operating in a multi-pair cable.

XS.dn: is a downstream PSD that is 10 dB above the signal spectrum that the SDSL transceiver under test transmits in downstream direction, into the LT side of the access network cable. This spectral profile, filtered by the two crosstalk coupling functions of sub-clause 2.3.2, will simulate the self-NEXT and self-FEXT for downstream transmission, generated by a high volume (in the order of tens) of similar SDSL systems operating in a multi-pair cable.

2.3.4.2. Alien crosstalk PSD profiles (is "alien" a correct English term for this?)

It is assumed in this technical specification that a mix of ISDN-BA (2B1Q), two-pair HDSL (2B1Q), and ADSL over ISDN (DMT) can serve as a fair representation of a near worst-case technology mix in a multi-pair cable where SDSL is deployed.
The worst case PSD representation of each component, is based on the PSD masks as specified in the associated ETSI specifications [*], [*] and [*]. The break frequencies of these masks are

summarised in table 5. The PSD masks are constructed with straight lines between these break frequencies, when plotted against a logarithmic frequency scale and a linear dB scale.

ISDN

[Hz]	[dBm]
1	-30
50k	-30
500k	-80
1.4M	-80
5M	-120
30M	-120

HDSL/2

[Hz]	[dBm]
1	-39
292k	-39
2.92M	-119
10M	-119

ADSL up		***ADSL down***	
[Hz]	**[dBm]**	**[Hz]**	**[dBm]**
1	-90	1	-90
50k	-90	50k	-90
80k	-81.86	80k	-81.86
138k	-34.5	138k	-36.5
276k	-34.5	1.104M	-36.5
614k	-90	3.093M	-90
1.22M	-90	4.545M	-140
1.63M	-140	11.04M	-140
11M	-140		

Table 5: Break frequencies of the PSD masks of individual transmission systems, other than SDSL.

Two spectral profiles are identified for noise model A: one for upstream and another for downstream transmission.

[XA.up]: is an upstream PSD that is specified in Table 6, in terms of break frequencies. Its 10 dB above the rounded power sum of the ISDN, the HDSL and the ADSL upstream PSD-masks that are specified in table 5. This spectral profile, filtered by the two crosstalk coupling functions of sub-clause 2.3.2, will simulate their contribution to the NEXT and FEXT for SDSL upstream transmission, generated by a high volume (each one in the order of tens) of these systems operating in a multi-pair cable.

[XA.dn]: is a downstream PSD that is specified in Table 6, in terms of break frequencies. Its 10 dB above the rounded power sum of the ISDN, the HDSL and the ADSL downstream PSD-masks that are specified in table 5. This spectral profile, filtered by the two crosstalk coupling functions of sub-clause 2.3.2, will simulate their contribution to the NEXT and FEXT for SDSL downstream transmission, generated by a high volume (each one in the order of tens) of these systems operating in a multi-pair cable.

XA.up

[Hz]	[dBm]
1	-19.5
47 k	-19.5
64 k	-24
270 k	-24
630 k	-56
1 M	-68
1.4 M	-70
3 M	-94
5 M	-106
10 M	-106

XA.dn

[Hz]	[dBm]
1	-19.5
47 k	-19.5
70 k	-25.3
290 k	-25.3
350 k	-27.1
450 k	-27.8
1.1 M	-27.8
3.1 M	-81.6
4 M	-106
10 M	-106

Table 6: Break frequencies of the XA.up and XA.dn PSD masks that are used to specify the noise model A spectra in sub-clause 2.3.5 and 2.3.6. The levels are defined with respect to impedance R_v, as specified in sub-clause 2.1.2

2.3.5. NEXT noise models [G1.xx]

The NEXT noise generator represents all impairment that is identified as crosstalk noise from a predominantly Near End origin. The PSD of this noise generator is a function of PSD profiles only due to a given worst case assumption of service/transmission system mix in a multi-pair cable. It 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. The NEXT noise generator is uncorrelated with all other sources in the impairment generator, and the noise profiles described below shall be applied to the receiver under test.

NEXT noise model [**G1.LT.A**] shall be used when the impairment noise is applied at the LT end in noise scenario A. This noise shall be created by the addition of two uncorrelated noise sources, that are random in nature and near Gaussian distributed, as specified in sub-clause 2.3.3. The PSD of the first source has profile [XS.dn] as specified in sub-clause 2.3.4.1, and the second source has profile [XA.dn] as specified in sub-clause 2.3.4.2. These profiles shall be met for all frequencies between 1 kHz to 1 MHz. Noise source [XS.dn] is uncorrelated with the SDSL system under test. For measuring PSD the measurement bandwidth shall be equal to or less than 1 kHz.

NEXT noise model [**G1.NT.A**] shall be used when the impairment noise is applied at the NT end in noise scenario A. This noise shall be created by the addition of two uncorrelated noise sources, that are random in nature and near Gaussian distributed, as specified in sub-clause 2.3.3. The PSD of the first source has profile [XS.up] as specified in sub-clause 2.3.4.1, and the second source has profile [XA.up] as specified in sub-clause 2.3.4.2. These profiles shall be met for all frequencies between 1 kHz to 1 MHz. Noise source [XS.up] is uncorrelated with the SDSL system under test. For measuring PSD the measurement bandwidth shall be equal to or less than 1 kHz.

2.3.6. FEXT noise models [G2.xx]

The FEXT noise generator represents all impairment that is identified as crosstalk noise from a predominantly Far End origin. The PSD of this noise generator is a function of PSD profiles only due to a given worst case assumption of service/transmission system mix in a multi-pair cable. It 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. The FEXT noise generator is uncorrelated with all other sources in the impairment generator, and the noise profiles described below shall be applied to the receiver under test.

FEXT noise model [**G2.LT.A**] shall be used when the impairment noise is applied at the LT end in noise scenario A. This noise shall be created by addition of two uncorrelated noise sources, that are random in nature and near Gaussian distributed, as specified in sub-clause 2.3.3. The PSD of the first source has profile [XS.up] as specified in sub-clause 2.3.4.1, and the second source has profile [XA.up] as specified in sub-clause 2.3.4.2. These profiles shall be met for all frequencies between 1 kHz to 1 MHz. Noise source [XS.up] is uncorrelated with the SDSL system under test. For measuring PSD the measurement bandwidth shall be equal to or less than 1 kHz.

FEXT noise model [**G2.NT.A**] shall be used when the impairment noise is applied at the NT end in noise scenario A. This noise shall be created by the addition of two uncorrelated noise sources, that are random in nature and near Gaussian distributed, as specified in sub-clause 2.3.3. The PSD of the first source has profile [XS.dn] as specified in sub-clause 2.3.4.1, and the second source has profile [XA.dn] as specified in sub-clause 2.3.4.2. These profiles shall be met for all frequencies between 1 kHz to 1 MHz. Noise source [XS.dn] is uncorrelated with the SDSL system under test. For measuring PSD the measurement bandwidth shall be equal to or less than 1 kHz.

2.3.7. Background noise model [G3]

The background noise generator represents all impairments that are identified as (remaining) cross-talk noise, but from unidentified origin. It is not related to the cable, because the origin of this noise has not been explicitly identified.
The noise profile described below shall be applied to the receiver under test.

The background noise generator is uncorrelated with all other sources in the impairment generator, and its random in nature and near Gaussian distributed, as specified in sub-clause 2.3.3. The PSD level of the background noise shall be at least -140 dBm, for all frequencies between 1 kHz to 1 MHz. This level is defined with respect to impedance R_V, as specified in sub-clause 2.1.2.

> Ed. Is -140 dBm a realistic minimum for the impairment noise? A value like this will also set a limit to the low-noise requirements of an impairment generator implementation. When such a generator is implemented as an Arbitrary Waveform Generator, the quantisation noise of the DA-convertor will put a limit on the minimum noise level that can be generated.

2.3.8. White noise model [G4]

The white noise generator represents the ever present noise which is intended to be representative of the thermal noise in the DSL line termination.

> Ed. Thermal noise of a 135Ω resistor can be ignored, with respect to -140 dBm. So for the time being, we propose to set the white noise level to zero, and skip this generator.

2.3.9. 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 SDSL band. 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.

2.3.10. 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.

2.3.11. 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

2.4. Transmission Performance tests

2.4.1. Bit error ratio requirements

The SDSL system 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).

2.4.2. 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.

2.4.2.1. 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 5, equally over the full SDSL frequency band, 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 Δ**x** 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.

2.4.2.2. Measuring impulse noise margin

Ed. This whole issue is subject for further study

2.4.3. Upstream tests

Several SDSL performance tests shall be carried out to prove adequate upstream performance. These tests are specified in Table 7. 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 7: Test matrix with composition of noise models in the upstream tests

2.4.4. Downstream tests

Several SDSL performance tests shall be carried out to prove adequate downstream 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 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 8: Test matrix with composition of noise models in the Downstream tests

2.5. 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 SDSL 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 a number of cable types which are representative of existing European metallic access networks. See [I-3] for an overview of country specific line constants.

The primary cable parameters vary with the frequency. Their typical values may be calculated at any frequency (up to 30 MHz) by using the empirical models contained in Table A.1. The line constants are given in Table A.2 and Table A.3 and may be used (together with the equations) to calculate the values given in Figure 14 and determine the transmission mode characteristics of the test loops contained in the main body of this TS.

In the case that real cables are used for these test loops, the estimated lengths of these cables are summarised in Table A.4. Their actual lengths may deviate from this because real test-loops have to meet the insertion loss requirements instead of length requirements.

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

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

Table A.1 : Formal models for the BT and the KPN cable parameters in the test loops. Both models are equally valid from DC to 30 MHz when using the appropriate parameter sets and values given in Table A.2 and Table A.3. Note that the BT models are specified in kilometers, and the KPN models in meters.

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

Table A.2 : Line constants for the BT cables in the test loops.

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

Table A.3 : Line constants for the KPN cables in the test loops

Annex B [informative]: Cable information

The following material, though not specifically referenced in the body of the TS, gives supporting information regarding cable construction.

Cable type BT_dw8

Single pair dropwire. Flat twin (i.e. untwisted). 1.14 mm cadmium copper conductors. PVC insulated. No steel strength member.

Cable type BT_dwug

Multiple pair. 0.5 mm solid copper conductors. Polyethylene insulated. Predominantly used for underground distribution.

Cable type KPN_L1

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 cable has 50 quads in a bundle, but similar cables may combine up to 450 quads in the same bundle.

Cable type KPN_R2

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).