TITLE **Revised noise models for SDSL**

PROJECT SDSL

SOURCE: KPN Research, The Netherlands
FSAN-xDSL working group.

SUPPORTED BY:
Rob van den Brink, KPN
Don Clarke, BT
John Cook, BT
Lorenzo Magnone, CSELT (Telecom Italia Group)
Rosaria Persico, CSELT (Telecom Italia Group)
Mathias Friese, Deutsche Telekom AG
Thomas Kessler, Deutsche Telekom AG
Mikael Isaksson, Telia
Daniel Bengtsson, Telia
Marc Vautier, France Telecom

CONTACT R.F.M. van den Brink tel: +31 70 3325389
KPN Research, fax: +31 70 3326477
PO Box 421 email: R.F.M.vandenBrink@research.kpn.com
2260 AK Leidschendam
The Netherlands

STATUS Proposal

ABSTRACT This contribution is a revised proposal on noise models, for performance testing on SDSL. The underlying scenario's have been redefined into three versions: a high penetration, a medium penetration and a legacy scenario. This proposal addresses the length dependency of the FEXT, and is supported by a large number of operators that work together in FSAN.

# 1. Basic FSAN Proposal

At the Sophia Antipolis meeting of ETSI-TM6, it was agreed to combine the various proposals [1,2,3] on SDSL noise models into a combined proposal that is supported by a large number of operators. KPN was invited at the FSAN meeting of Darmstadt (26-28 january 1999), to have this solved in close co-operation with other operators. This contribution describes the noise models for performance testing that resulted from this FSAN meeting.

Three scenario's have been identified to be applied to SDSL testing. Each scenario results in a length dependent PSD description of noise models, one to be injected at the LT-side, and another to be injected at the NT-side of the SDSL modem link under test.

- **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".

The three scenario's are based on a technology mix of SDSL interferers (self crosstalk) and non-SDSL interferers (alien crosstalk). Note that the "ADSL over ISDN" and "ISDN/2B1Q" systems in these scenario's may share the same wire pair, but contribute to the total PSD as individual systems.

- ***Technology mix of model A***

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

- ***Technology mix of model B***

| | | |
|---|---|---|
| $P_1$ | 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 of model C***

| | | |
|---|---|---|
| $P_1$ | 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 $R_V$ = 135Ω, the design impedance of HDSL, ISDN, VDSL.

- The PSD of the alien crosstalk sources $\{P_{XA}\}$, is the FSAN crosstalk sum of $\{P_1, P_2, \dots P_n\}$ as described in section 3 and in [4]. The resulting PSD's are specified in table 1 and 2. Each noise model has identified an LT-PSD as well as an NT-PSD, to distinct upstream testing from downstream testing.
- The contribution of the self crosstalk sources (from SDSL only) was not discussed at this FSAN meeting, and therefore this remains to be decided.
- The PSD of the combined crosstalk sources of the noise model is the FSAN crosstalk sum (see section 3) of alien crosstalk and self crosstalk $\{P_{XA}, P_{XS}\}$.

The composition of the impairment noise, that is to be injected in the testloops, results mainly from filtering the above combined crosstalk sources by the crosstalk coupling functions for NEXT and FEXT. The associated impairment generator, as described in detail in TD27 [1], has four individual sources (G1,G2,G3,G4) identified for this purpose:

- The PSD of generator G1 equals one of the combined crosstalk noise. The LT-PSD of a noise model shall be used for upstream testing and the NT-PSD for downstream testing.
- The PSD of generator G2 equals one of the combined crosstalk noise. The NT-PSD of a noise model shall be used for upstream testing and the LT-PSD for downstream testing.
- The PSD of generator G3 is set to zero.
- The PSD of generator G4 is white and set to –140dBm/Hz, to represent background noise.

# 2. Calculated noise models

Each noise model is subdivided into two parts: downstream noise at the LT-side and upstream noise at the NT-side. The noise models address the PSD levels of generator G1 and G2, as defined in TD27 [1], for upstream testing. The PSD of G1 and G2 are to be interchanged when testing the opposite direction.

[XA.LT.#]: are downstream PSD's of alien crosstalk noise. They are specified in Table 1, in terms of break frequencies. Their spectral profiles originate from a mix of interferers, as described in section 3. These spectral profiles, filtered by the two crosstalk coupling functions as specified in TD27 [1], will represent their contribution to the FEXT, while testing downstream transmission, and to the NEXT while testing upstream transmission.

| 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 1: Break frequencies of the "XA.LT.#" PSD masks that specify noise spectra as used in TD27 [1]. The PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.**

[XA.NT.#]: are upstream PSD's of alien crosstalk noise. They are specified in Table 2, in terms of break frequencies. Their spectral profiles originate from a mix of interferers, as described in section 3. These spectral profiles, filtered by the two crosstalk coupling functions as specified in TD27 [1], will represent their contribution to the NEXT, while testing downstream transmission, and to the FEXT while testing upstream transmission.

| 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 2: Break frequencies of the "XA.NT.#" PSD masks that specify the alien noise spectra as used in TD27 [1].The PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.**

# 3. 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 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 components of this mix are:

- SDSL (not yet defined),
- ISDN-BA (2B1Q),
- HDSL (2-pair 2B1Q),
- ADSL (DMT over POTS, DMT over ISDN, DMT-lite)
- ISDN-PRI (HDB3)

The inclusion in this mix of systems like ISDN-BA (4B3T) and HDSL (2-pair CAP) has 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 can be described by simplified PSD masks, and the break frequencies of these masks are summarised in table 3 and 4. The PSD masks in table 3 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 3: 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.**

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

$P_0 = 12.4$ 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 4: PSD mask of the ISDN-PRI (HDB3) system, as function of the frequency.**

The PSD levels, of the sources in table 3 and 4, 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.

## 3.1 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 1 and 2. It is the rounded envelope of the calculated combined PSD.

## 3.2 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 1 and 2. It is the rounded envelope of the calculated combined PSD.

## 3.3 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 1 and 2. It is the rounded envelope of the calculated combined PSD.

# 4. References

[1] Rob F.M. van den Brink, KPN, *Proposal for SDSL performance tests*, ETSI-TM6 contribution TD27 (984t27a0), Vienna, Sept 1998.
[2] Marc Kimpe, ADTRAN, *Performance of TS 101 135 2-pair HDSL systems under various noise Models*, ETSI-TM6 contribution TD30 (985t27a0), Sophia Antipolis, Nov 1998.
[3] Thomas Kessler, DTAG, *Using FSAN noise models for SDSL*, ETSI-TM6 contribution TD49 (985t49a0), Sophia Antipolis, Nov 1998.
[4] FSAN xDSL working group, *Proposal for crosstalk combination method*, ETSI-TM6 contribution TD23 (985t23a0), Sophia Antipolis, Nov 1998.