TITLE	**Realistic ADSL noise models**
PROJECT	ADSL (SP-1 of the LL on RTR/TM- 06006)

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ABSTRACT This proposal details a full specification of the noise models that makes ADSL performance tests realistic. The approach is similar to the SDSL and VDSL performance tests approach, but dedicated to ADSL. It covers performance tests for "ADSL over POTS" as well as "ADSL over ISDN". If FDD-based variants of ADSL will be included in ETSI specifications, and extention of the here proposed noise models makes sense, then noise models dedicated to FDD-ADSL can be added.

1. Why an update of the ADSL noise models?

There is consensus within ETSI-TM6 that the existing noise models A and B, as specified in ETSI reports on ADSL, are too unrealistic [1] for being representative of real access networks.

It is generally agreed that the noise model approach that has been developed for VDSL and SDSL [2,3,4] yields a far more realistic representation of the impairment in real network environments. That approach for defining crosstalk noise for testing is essentially a weighed power sum of several individual disturbers, multiplied by realistic NEXT and FEXT coupling functions. The major improvements of that approach are:

- The total impairment is based on well-defined and realistic assumptions. The assumed PSD templates for each individual disturber, and crosstalk coupling assumptions are commonly accepted [4]. (See section 4.)
- The overall noise that shall be generated for ADSL testing is based on the assumption that many ADSL systems will share the same cable bundle or binder group. This caused that the revised noise levels are significantly higher[1] than was specified for the existing noise models A and B.
- The total impairment, that is to be injected at the receiver side of the ADSL modem under test varies with the testloop length. This is common for real access cables.

In this contribution a uniform approach is proposed for "ADSL over POTS" as well for "ADSL over ISDN". It is also applicable to any non-ETSI ADSL systems, including ADSL-lite, but these are beyond the scope of this contribution. Although the proposed approach is unified [3] for various xDSL systems, the actual impairment noise in this contribution is ADSL specific.

Spin-off: "FSAN assumptions"
These individual disturber templates are used by FSAN members for simulating purposes, since they are the most representive PSDs for disturbing systems. To harmonize simulation, it is recommended to refer to the PSD templates in this contribution as the "*FSAN-assumptions on disturber PSD's*".

2. The rationale behind this FSAN Proposal

Four scenario's have been identified to be applied to ADSL testing, which are similar to the scenarios that have been defined in the recent past for SDSL.

Each scenario is characterized in a technology mix of different xDSL transmission systems. For combining the individual disturbers into an *equivalent disturbance* of this mix, the FSAN noise combination method is used, as described in [4] and [3] .
The actual noise that is to be injected at the receiver side of the ADSL modem under test, equals this equivalent disturbance, multiplied with NEXT and FEXT coupling functions (as specified in detail in [3]). The result is a length dependent PSD description of noise models (different for LT and NT side), extracted from a fixed equivalent disturbance specification.

The choosen technology mix is summarised below. It is included here to highlight the rationale behind this proposal, but this list is not for inclusion in the ADSL standard.

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

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

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

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

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

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

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

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

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

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

The FSAN crosstalk sum for four individual PSD's is used for calculating the total equivalent disturbance of this technology mix. This sum equals for a mix of 4 technologies (P in W/Hz):

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

The equivalent disturbance *P* that shall be used, varies with the ADSL modem that is tested. This means different equivalent disturbance specifications for different ADSL variants, such as:

- ADSL over POTS - Echo cancelled
- ADSL over POTS - FDD based
- ADSL over ISDN - Echo cancelled
- ADSL over ISDN - FDD based
- ADSL-lite

Currently, only the specification of echo cancelled ADSL systems (over POTS and over ISDN) are covered by ETSI standards. That's why section 3 is restricted to these two variants.

For adding noise models dedicated to the FDD variants of ADSL, it is required that their spectral masks are covered by ETSI standards.
Vendors of FDD ADSL equipment are invited to contribute FDD masks.

Since the PSD of echo cancelled ADSL systems have been well defined, there was no need to isolate this PSD in a self-crosstalk component, separated from all the other disturbers (alien crosstalk). This convenience has simplified the noise specification for ADSL significantly, compared to the noise specification for SDSL and VDSL.

The impairment generated by SDSL, is based on the PSD assumptions that defined in section 4, and taken from [5,6]. This PSD assumption is not stable yet within ETSI-TM6, but a simple re-calculation of the proposed equivalent noise for ADSL testing can adapt to modified SDSL PSDs.

3. Proposed noise models

For xDSL testing, several noise models for crosstalk have been defined. For each model, two spectral profiles are identified: one for stressing upstream signals and one for stressing downstream signals. Each PSD profile originates from a mix of disturbers, as described in section 4.

- The profiles X.LT.# in this section describe the total *equivalent disturbance* of a technology mix that is virtually co-located at the LT end of the testloop. This noise is represented by equivalent disturbance generator G1 (see [3]), when stressing upstream signals, and by equivalent disturbance generator G2 when stressing downstream signals.
- The profiles X.NT.# in this section describe the total *equivalent disturbance* of a technology mix that is virtually co-located at the NT end of the testloop. This noise is represented by equivalent disturbance generator G2 (see [3]), when stressing upstream signals, and by equivalent disturbance generator G1 when stressing downstream signals.

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

The equivalent disturbance, filtered by the NEXT and FEXT coupling functions as specified in Permanent Document TM6(98)10 [3], will represent the crosstalk noise that is to be injected in the test setup. Mark that the PSD levels of equivalent disturbance generator G1 and G2 are interchanged when changing upstream testing into downstream testing.

The equivalent disturbance does not include the multi tone impairment to test the imunity to ingress, because that topic is addressed separately in Permanent Document TM6(98)10 [3].

3.1. Noise for ADSL over POTS systems (E.C.)

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

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

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

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

Table 1: Break frequencies of the "X.LT.#" PSD masks that specify the equivalent disturbance for testing (echo cancelled) ADSL over POTS systems. The PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.

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

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

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

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

Table 2: Break frequencies of the "X.NT.#" PSD masks that the equivalent disturbance for testing (echo cancelled) ADSL over POTS systems. The PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.

3.2. Noise for ADSL over ISDN systems (E.C.)

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

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

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

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

Table 3: Break frequencies of the "X.LT.#" PSD masks that specify the equivalent disturbance for testing (echo cancelled) ADSL over ISDN systems. The PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.

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

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

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

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

Table 4: Break frequencies of the "X.NT.#" PSD masks that specify the equivalent disturbance for testing (echo cancelled) ADSL over ISDN systems. The PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.

3.3. Graphic representation of the noise

Figure 1 illustrates the noise levels, that are be injected at the testloop, near the receiver side of ADSL over POTS performance tests. These examples hold for the special case that the loop is a "KPN_L1" loop of 3 km.
Figure 2 illustrates the same, but for ADSL over POTS performance tests.

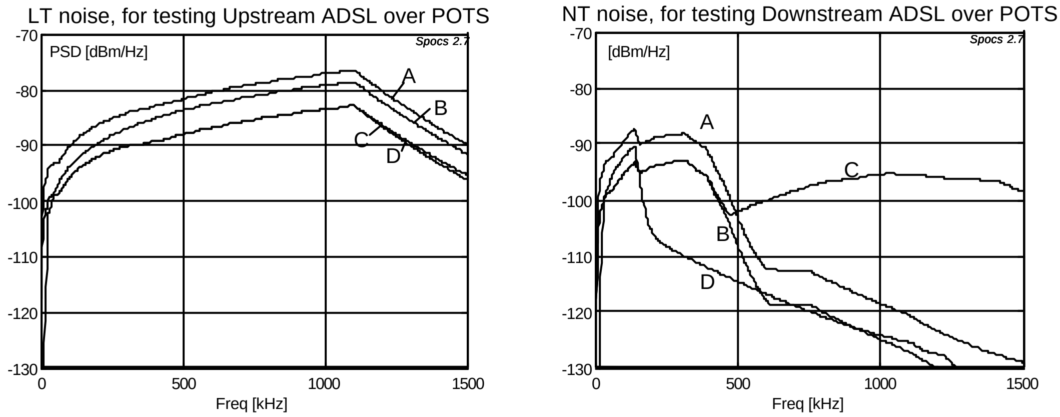

Figure 1. The PSD level of the impairment noise that is to be injected at the receiver side of an "ADSL over POTS" performance tests, calculated for a 3 km "KPN_L1" testloop.

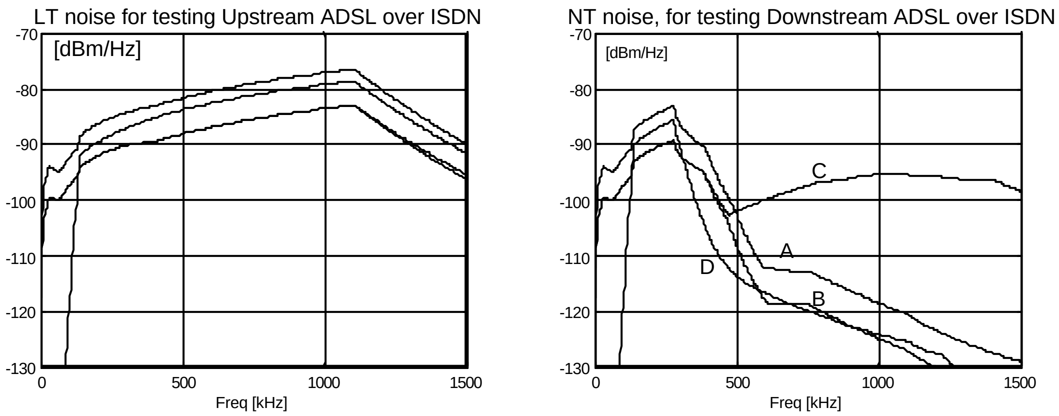

Figure 2. The PSD level of the impairment noise that is to be injected at the receiver side of an "ADSL over ISDN" performance tests, calculated for a 3 km "KPN_L1" testloop.

4. FSAN Assumptions on PSDs

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.

The individual disturbers can be described by simplified PSD templates[1], and the break frequencies of these templates are summarised in table 5 and 7. The PSD templates in table 5 are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.

[1] This ISDN/4B3T PSD is based on the ***mask*** that is specified in ETSI standards, and not on a ***template*** for the expected average value. Using this PSD for performance simulation purposes may therefore cause results that are a bit pessimistic. This has no consequences to the ADSL noise models, since the ISDN/4B3T PSD is not used here. An update of this PSD, for simulation purposes in general, is for further study.

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

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

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

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

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

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

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

Table 6: PSD mask of the SDSL system, as a function of the frequency. (assuming 2.304 kb/s datarate, 8kb/s overhead, 3 bits per symbol)

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

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

Table 7: PSD mask of the ISDN-PRI (HDB3) system, as a function of the frequency.

5. References

[1] Rob van den **Brink**, KPN, *Realistic performance tests for ADSL*, ETSI-TM6 contribution TD09 (992t20a0), Grenoble, May 1999.

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

[3] Rob van den **Brink**, KPN, *Performance tests for SDSL and other long-range xDSL systems*, ETSI-TM6 permanent documents TM6(98)10, (980p10a2), Edinburgh, Sept 1999.

[4] **KPN/FSAN** xDSL working group, *Update of SDSL noise models, as requested by ETSI-TM6*, ETSI-TM6 contribution TD22 (993t22a0), Edinburgh, Sept 1999.

[5] Jim **Girardeau** et. al.: *"Scalable PSD for SDSL"* (Source: Adtran, Level One Communications. Alcatel KE, Conexant, Lucent. Globespan, Metalink, Infineon, Siemens), ETSI-TM6 working document WD18 (993w18a0), Edinburgh, Sept 1999.

[6] **KPN/FSAN** xDSL working group, *FSAN position on the PSD proposal for SDSL in WD18*, ETSI-TM6 contribution TD04 (994t04a0), Amsterdam, Nov 1999.