TITLE **Noise models for the FDD variants of ADSL**

PROJECTS ADSL

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ABSTRACT The ADSL impairment generator of the current ADSL draft covers four noise models for "ADSL over POTS" and another four noise models for "ADSL over ISDN". Models for the FDD variant are currently lacking. This contribution adds four noise models for "ADSL.FDD over POTS" and another four noise models for "ADSL.FDD over ISDN". They are an extention to the current FSAN noise models for (full) ADSL, by using FDD ADSL as self disturber in stead of (full) ADSL.

1. Introduction

During the Amsterdam meeting of ETSI-TM6, realistic noise models for ADSL were proposed [1,2] and supported by operators that work together within the FSAN xDSL working group. As was stated explicitly in [1] these models were dedicated to full ADSL and that an extention to these models, fully dedicated to the FDD variants of ADSL, would make sense. Such an extention to the current FSAN models requires a PSD description of FDD based ADSL systems.

In the past three month, many e-mail discussions and telephone conferences has resulted [3,4] in some informal consensus about the nominal PSD of these FDD-based systems. These nominal PSD values are vital input for dedicating the FSAN noise models to FDD based ADSL systems.

This contribution is based on the assumption that ETSI-TM6 achieves formal consensus about this nominal PSD [3,4]. Furthermore, it uses the same rationale from [1] so that the proposal in this contribution is mainly the result of computational effort.

2. The rationale behind this proposal

2.1. The FSAN disturber mix for ADSL

Four scenario's have been identified in the past by FSAN [1] for applying to ADSL testing, which are similar to the scenarios that have been defined for SDSL [6].
Each scenario is characterized in a disturber mix of different xDSL transmission systems.
The choosen disturber mix from [1] is summarised below. It is included here to highlight the rationale behind this proposal, but this list is not intended for inclusion in the ADSL standard.

- ***FSAN Disturber 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)

- ***FSAN Disturber 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)

- ***FSAN Disturber 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)

- ***FSAN Disturber 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.

2.2 How to combine the FSAN mix; old and new ways

The disturber mixtures of the ADSL noise models are combined into two "fixed" equivalent disturbers [5,7], that are to be multiplied by length dependent crosstalk coupling functions:

- The equivalent disturbers are a replica of all co-located disturbers; resulting in one equivalent disturber at the LT-side of the testloop and another one at the NT-side of the testloop.
- the crosstalk coupling functions represent NEXT and FEXT, and these functions are dependent on the length and type of the testloop.

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.

The level of the equivalent disturber is a weighed crosstalk sum of all co-located disturbers, while some of these disturbers have different terminating impedances. This aspect has been ignored in the past [1,5,6,7], was not well understood and resulted in different interpretations of the FSAN crosstalk sum. The reason was that the FSAN crosstalk sum is developed for summing noise at the victim modem under test, and not at the disturber side of the crosstalk coupling. New methods have recently being developed [8] for handling crosstalk summing in a multi-impedance invironment. This bring us for the choice on how to use these "new" calculation methods:

(a) should all ADSL noise models use the "new" method (i.e. revise the noise models for full ADSL)
(b) should the "new" method be used for FDD-ADSL while leaving the "old" method for full ADSL
(c) should the "old" method be used for both EC and FDD noise models.

Option (a) may look the prefered one, but has the consequence that noise models that have been stable for more that one and a half year have to change, and that all effort in evaluating performance objectives for ADSL over ISDN becomes obsolete.
Option (b) is simple to do, but has the consequences that comparing performance between full ADSL and FDD-ADSL will become complicated.
Option (c) is simple too, but has only the (minor) consequence that the equivalent disturbers are not a replica of the underlying disturber mix according to the latest views [8].

In this proposal the "old" method (option c) is choosen for reasons of consistency. [3,4]

2.3 Difference between "old" and "new" ways

The consequence of prefering the "old" method t [1,5,6,7] of crosstalk summing over the "new" one [8] is small but not neglectable. To quantify this difference, a more detailed description is required about how the noise of the equivalent disturbers was evaluated in [1].
The FSAN crosstalk sum for four individual PSD's was used in [1] for calculating the total equivalent disturbance of this technology mix. This sum equals for a mix of 4 technologies (P in W/Hz):

in terms of voltages:	$U^2_{x,tot} = (U_{x1}^{2\cdot Kn} + U_{x2}^{2\cdot Kn} + U_{x3}^{2\cdot Kn} + U_{x4}^{2\cdot Kn} + ...)^{1/Kn}$
in terms of powers:	$P_{x,tot} = (P_{x1}^{Kn} + P_{x2}^{Kn} + P_{x3}^{Kn} + P_{x4}^{Kn} + ...)^{1/Kn}$

at K_n=1/0.6

Although the text in [1] suggests that the crosstalk sum was evaluated in terms of powers, in reality the level of the equivalent disturber was evaluated in a different way.

- for noise model A,B and C, the noise was added in terms of voltages. More precisely, in terms of the voltage $U=\sqrt{(P/R)}$ at the terminals of each disturber, when terminated with their design impedance R. When the square of these voltages was summed, the result was transformed back to equivalent noise power into the normalization impedance of 135Ω.
- for noise model D, the noise was directly added in terms of powers, due to the extreme simplicity of this noise model. More precisely: by adding the required 10.1 dB to the available power to obtain the equivalent noise power.

In a single impedance environment (such as at the victim side), all these different interpretations will give the same result, but this does not hold in a multi impedance environment [8] (such as at the disturber side).
In [8] is demonstrated that neither the power method nor the voltage method will give the correct result, since both methods ignore cable impedance completely. Nevertheless, the power method makes the smallest error, as shown in [8]. That's why it makes sense to analyse the diference between the two in the special case of the FSAN disturber mix:

Noise Model	disturber	"old" method interpretation in [1]	"new" method described in [8]	difference (linear)	difference (in dB)
model A, B, C	ISDN/2B1Q	$U_1 = \sqrt{(P_1 \times 135)}$	$U_1 = \sqrt{(P_1 \times 135)}$	$\sqrt{(135/135)}$	0 dB
	HDSL/2B1Q	$U_2 = \sqrt{(P_2 \times 135)}$	$U_2 = \sqrt{(P_2 \times 135)}$	$\sqrt{(135/135)}$	0 dB
	ADSL	$U_3 = \sqrt{(P_3 \times 100)}$	$U_3 = \sqrt{(P_3 \times 135)}$	$\sqrt{(135/100)}$	**1.30 dB**
	SDSL	$U_4 = \sqrt{(P_4 \times 135)}$	$U_4 = \sqrt{(P_4 \times 135)}$	$\sqrt{(135/135)}$	0 dB
	ISDN-PRI/HDB3	$U_5 = \sqrt{(P_5 \times 130)}$	$U_5 = \sqrt{(P_5 \times 135)}$	$\sqrt{(135/130)}$	**1.14 dB**
model D	ADSL	$P = P_1$	$P = P_1$	1	0 dB
result	eq. disturber	$P_{tot} = (\Sigma U_x^2) / 135$	$P_{tot} = (\Sigma U_x^2) / 135$	1	0 dB

The above table shows that "old" and "new" method yield the same result, except for ADSL disturbers (model A,B and C) and for the ISDN-PRI/HDB3 disturber (noise model C). Since ADSL is not the only disturber, the overall difference is less than 1.3 dB.

2.4 Effective disturber mix, due to the "old" method

The consequence of using the "old" method is that ADSL and ISDN-PRI/HDB3 appears to be a more silent disturber then would have been if the "new" crosstalk sum was used [8]. In other words, according to the latest views [8] on crosstalk summing the current noise models for (full) ADSL represent the following disturber mix below. Mark the (small) difference from the FSAN disturber mix.

- ***Effective disturber 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) + **<u>12.2</u> dB** (occupying about **<u>108</u>** wire pairs)
  - P_4 SDSL (2.3Mb/s) + 11.7 dB (occupying about 90 wire pairs)

- ***Effective disturber 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) + **<u>5.8</u>** dB (occupying about **<u>9</u>** wire pairs)
  - P_4 SDSL (2.3Mb/s) + 7.1 dB (occupying about 15 wire pairs)

- ***Effective disturber 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) + **<u>5.8</u>** dB (occupying about **<u>9</u>** wire pairs)
  - P_4 SDSL (2.3Mb/s) + 7.1 dB (occupying about 15 wire pairs)
  - P_5 ISDN-PRI/HDB3 + **<u>2.46</u>** dB (occupying about **<u>3</u>** wire pairs)

- ***Effective disturber mix of model D (pure self-crosstalk scenario)***
  - P_1 ADSL (under test) + 10.1 dB (occupying about 49 wire pairs)

The above effective mix (due to using the "old" method) shows that there is a difference between the "old" and the "new" method, but that this difference is not significant enough to declare the current noise models for (full) ADSL obsolete.
Moreover, this translation between dB and number of wire pairs is fully based on cables in which the 99% power sum of N disturbers increases with a factor $N^{0.6}$. When other type of cables were used for this analysis, in which this sum increases with a factor $N^{0.7}$ or $N^{0.8}$ (as indicated in [8]), then the effective disturbe mix would have been significantly different.
This illustrates how insignificant a "precise" description of the effective disturber mix is. It supports the decision to prefer *consistency* in calculation methods over using the latest view on crosstalk summing. Therefore the noise models for the FDD variants of ADSL are based on the "old" calculation method used in [1].

2.5. The assumed PSDs of the individual disturbers

A precise description of the PSDs of the individual disturbes is provided in Section 4. They are based on the following rationale:

	used in [1] **(full) ADSL**	**used in current proposal** **FDD variants of ADSL**	**differences**
ISDN/2B1Q	FSAN assumptions [1], based on estimated nominal value	FSAN assumptions [1], based on estimated nominal value	unchanged
HDSL/2B1Q	FSAN assumptions [1], based on estimated nominal value	FSAN assumptions [1], based on estimated nominal value	unchanged
ADSL **(under test)**	FSAN assumptions [1], based on estimated nominal value of full ADSL	consensus PSD [3,4], based on nominal values of FDD-ADSL	significant differences
SDSL	nominal SDSL spectrum proposed at Edinburg meeting [11]	nominal SDSL spectrum defined in ETSI standard [9]	minor change
ISDN-PRI/HDB3	FSAN assumptions [1], based on DTAG observations	FSAN assumptions [1], based on DTAG observations	unchanged

3. Proposed noise models

For xDSL testing, several noise models for crosstalk have been defined. For each model, two equivalent disturbers are identified: one for stressing upstream signals and one for stressing downstream signals. The PSD profile of each equivalent disturber 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 [7]), 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 [7]), 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 PSD of the equivalent disturbers are specified in table 1 to 4. An independent verification [10] of these tables confirms that there are no apparent errors in the proposed noise models.

The equivalent disturbance, filtered by the NEXT and FEXT coupling functions as specified in Permanent Document TM6(98)10 [7], 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 noise, because that topic is addressed separately in Permanent Document TM6(98)10 [7].

3.1. Equivalent disturbers for ADSL.FDD over POTS

X.LT.A [Hz]	*135 W* [dBm/Hz]
1	-20.1
15 k	-20
30 k	-21.6
45 k	-24.1
64 k	-27.6
137.99 k	-27.7
138 k	-26.1
277 k	-26.8
407 k	-27.8
1.106 M	-27.8
4.544 M	-96.2
30 M	-96.2

X.LT.B [Hz]	*135 W* [dBm/Hz]
1	-25.7
15 k	-25.6
30 k	-27.1
45 k	-29.6
65 k	-32.6
137.99 k	-32.8
138 k	-31.7
272 k	-32.5
414 k	-34.2
1.103 M	-34.2
4.360 M	-101.6
30 M	-101.6

X.LT.C [Hz]	*135 W* [dBm/Hz]
1	-25.8
15 k	-25.6
30 k	-27.2
45 k	-29.7
63 k	-32.6
137 k	-32.8
139 k	-31.7
294 k	-32.7
417 k	-34.2
1110 k	-34.2
2160 k	-66.1
2400 k	-63.6
2550 k	-63.8
20 M	-101.6
30 M	-101.6

X.LT.D [Hz]	*135 W* [dBm/Hz]
1	-87.4
3.99 k	-87.4
4 k	-82.4
80 k	-62.4
137.99 k	-34.1
138 k	-29.9
1104 k	-29.9
3093 k	-79.9
4545 k	-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.FDD 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]
1	-20.0
15 k	-20.0
24 k	-20.9
30 k	-21.0
45 k	-23.0
60 k	-24.7
138 k	-24.9
151 k	**-28.0**
207 k	**-28.7**
300 k	**-30.3**
358 k	**-32.8**
407 k	**-36.7**
500 k	**-48.6**
594 k	**-62.3**
755 k	**-62.3**
1059 k	**-73.7**
1221 k	**-75.5**
1400 k	**-77.9**
2532 k	-96.2
30 M	-96.2

X.NT.B [Hz]	*135 W* [dBm/Hz]
1	-25.8
15 k	-25.6
24 k	-26.5
30 k	-26.8
61 k	-30.5
138 k	-30.8
149 k	**-33.0**
200 k	**-33.5**
308 k	**-35.2**
375 k	**-38.5**
456 k	**-46.9**
605 k	**-68.4**
755 k	**-68.4**
980 k	**-77.3**
1128 k	**-80.8**
1402 k	**-83.7**
2570 k	-101.6
30 M	-101.6

X.NT.C [Hz]	*135 W* [dBm/Hz]
1	-25.8
2 k	-25.8
15 k	-25.6
22 k	**-26.4**
30 k	**-26.8**
45 k	-28.8
60 k	-30.5
138 k	**-30.7**
150 k	**-33.0**
206 k	**-33.6**
338 k	-35.7
477 k	-47.8
788 k	-45.4
1064 k	-45.5
1500 k	-50.1
1800 k	-58.6
20 M	-101.6
30 M	-101.6

X.NT.D [Hz]	*135 W* [dBm/Hz]
1	-87.4
3.99 k	-87.4
4 k	-82.4
25.875 k	-27.9
138 k	-27.9
307 k	-79.9
1221 k	-79.9
1630 k	-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.FDD 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. Equivalent disturbers for ADSL.FDD over ISDN

X.LT.A [Hz]	*135 W* [dBm/Hz]
1	-20.1
14 k	-20
30 k	-21.5
45 k	-24.1
64 k	-27.7
105 k	-27.6
204 k	-28.7
253 k	-29.4
255 k	-26.7
412 k	-27.8
1104 k	-27.8
4543 k	-96.2
30 M	-96.2

X.LT.B [Hz]	*135 W* [dBm/Hz]
1	-25.8
2 k	-25.8
15 k	-25.6
30 k	-27.1
45 k	-29.6
66 k	-32.6
106 k	-32.6
200 k	-33.6
253 k	-34.3
254 k	-32.5
303 k	-32.9
417 k	-34.2
1104 k	-34.2
4439 k	-101.6
30 M	-101.6

X.LT.C [Hz]	*135 W* [dBm/Hz]
1	-25.7
15 k	-25.6
30 k	-27.2
45 k	-29.6
62 k	-32.6
107 k	-32.6
203 k	-33.6
253.8 k	-34.3
254 k	-32.5
300 k	-32.8
409 k	-34.2
1104 k	-34.2
1703 k	-53.6
2162 k	-66.2
2387 k	-63.7
2520 k	-63.6
2677 k	-65.5
20 M	-101.6
30 M	-101.6

X.LT.D [Hz]	*135 W* [dBm/Hz]
1	-79.9
93.1 k	-79.9
209 k	-51.9
253.99 k	-38.4
254 k	-29.9
1104 k	-29.9
3093 k	-79.9
4545 k	-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.FDD 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]	*135W* [dBm/Hz]
1	-20.1
15 k	-20
30 k	-21.5
45 k	-24.1
65 k	-27.6
111 k	-27.7
120 k	-24.8
275 k	-25.3
300 k	-29.1
403 k	-36
500 k	-48.6
614 k	-64.8
630 k	-64.8
651 k	-62.3
755 k	-62.4
1023 k	-72.7
1220 k	-75.5
1400 k	-77.9
2590 k	-96.2
30 M	-96.2

X.NT.B [Hz]	*135W* [dBm/Hz]
1	-25.8
2 k	-25.8
15 k	-25.6
30 k	-27.1
44 k	-29.6
64 k	-32.6
114 k	-32.6
120 k	-30.7
277 k	-31.4
305 k	-34.9
389 k	-39.3
500 k	-53.6
620 k	-70.1
633 k	-70.1
650 k	-68.2
758 k	-68.5
1071 k	-79.9
1222 k	-81.6
1398 k	-83.7
2479 k	-101.6
30 M	-101.6

X.NT.C [Hz]	*135W* [dBm/Hz]
1	-25.6
15 k	-25.6
30 k	-27.2
45 k	-29.6
62 k	-32.6
114 k	-32.7
120 k	-30.7
200 k	-31.0
276 k	-31.4
300 k	-34.6
377 k	-38.7
470 k	-47.8
802 k	-45.4
1024 k	-45.6
1309 k	-47.8
1587 k	-52.3
1900 k	-63.0
2011 k	-76.8
2283 k	-63.7
2492 k	-63.7
2716 k	-66.1
20 M	-101.6
30 M	-101.6

X.NT.D [Hz]	*135W* [dBm/Hz]
1	-79.9
50 k	-79.9
80 k	-71.8
120 k	-27.9
276 k	-27.9
614 k	-79.9
1221 k	-79.9
1630 k	-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.FDD 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.

4. PSD tables of individual disturbers

The PSD of the equivalent disturbers in the noise models, are based on the combined noise of different xDSL disturbers.
These individual disturbers can be described by simplified PSD templates, 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.

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

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

ADSL.FDD over POTS DMT	***Up 100 W***
[Hz]	**[dBm/Hz]**
0	-97.5
3.99 k	-97.5
4 k	-92.5
25.875 k	-38
138 k	-38
307 k	-90
1.221 M	-90
1.630 M	-110
30 M	-110

envelope power = 13.65 dBm @ 100W

ADSL.FDD over POTS DMT	***Down 100 W***
[Hz]	**[dBm/Hz]**
0	-97.5
3.99 k	-97.5
4 k	-92.5
80 k	-72.5
137.99 k	-44.2
138 k	-40
1.104 M	-40
3.093 M	-90
4.545 M	-110
30 M	-110

envelope power = 20.33 dBm @ 100W

ADSL.FDD over ISDN DMT	***Up 100 W***
[Hz]	**[dBm/Hz]**
0.001	-90
50 k	-90
80 k	-81.9
120 k	-38
276 k	-38
614 k	-90
1.221 M	-90
1.630 M	-110
30 M	-110

envelope power = 14.56 dBm @ 100W

ADSL.FDD over ISDN DMT	***Down 100 W***
[Hz]	**[dBm/Hz]**
0.001	-90
93.1	-90
209	-62
253.99	-48.5
254	-40
1104	-40
3093	-90
4545	-110
30000	-110

envelope power = 19.83 dBm @ 100W

Table 5: Break frequencies of the PSD masks of individual disturbers. For reasons of simplicity, the brick walls at 4 kHz are modelled as step between 3.99 kHz to 4 kHz.

$$P(f) = \frac{K_{SDSL}}{R_s \cdot f_{sym}} \cdot \frac{\text{sinc}^2(f/f_{sym})}{1 + (f/f_{HP})^{2 \cdot N}} \times \frac{1}{1 + (f_{LP}/f)^2} \text{ [W/Hz]}$$

$K_{SDSL} \approx 9.9$; Rs=135 Ω;
$f_{sym} = 2.312/3$ MHz; $f_{LP} = 5$ kHz; $f_{HP} = f_{sym}/2$; N=6;
$\text{sinc}(x) = \sin(\pi \cdot x) / (\pi \cdot x)$
out of band spectrum follows SDSL standard [9]; $f_o = 1$ Hz
midband: $P_m = 0.5683 \times 10^{-4} / ((f/f_0)^{1.5})$ [W/Hz]
highband: $P_h = -110$ [dBm]

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

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

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

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

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