TITLE **SDSL sensitivity to Ingress noise; preliminary measurements**

PROJECTS SDSL

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STATUS For information and discussion

ABSTRACT In order to support ETSI in their decision on what RFI tone levels are to be standardized in the SDSL performance test, additional experimental information is required on how sensitive these modems are to this kind of impairment. This contribution reports the observed reduction of noise margin in a preliminary experiment based on a prototype pre-standard SDSL modem, when impaired by the combination of ingress noise and crosstalk noise.

1. Introduction

The issue on what RFI tones are to be used as ingress noise in SDSL performance tests is still under study. The information that is currently available for such a decision includes:

- Several schemes of RFI tones have been proposed based on worst case assumptions, and an artificial set of modulated RFI tones has been identified with only a very weak harmonic relation. A summary of these schemes can be found in [1].
- BT has disclosed some measurements on ingress in real cables in their network [2].
- A simple but adequate description has been developed for how to specify the modulation of these tones [3].

What is missing is information on how will real SDSL modems respond, when they are stressed with ingress noise. Is the impact of worst-case ingress noise up to -40 dBm really as dramatic as expected or is it a non-issue?

The purpose of this contribution is to provide ETSI-TM6 with information on how sensitive SDSL modems are expected to be when impaired with worst-case ingress noise up to -40 dBm.

2. Description of the preliminary experiment

2.1. Prototype SDSL modem under test

The measurements are performed on a pre-ETSI-standard SDSL-lookalike prototype, that was provided to KPN for laboratorium experiments. The line rate of this prototype modem was fixed at some unknown value near 1 Mb/s. From the spectrum in figure 1 it was concluded that the symbol rate equals 248 kbaud. Assuming 4 bits/symbol gives a line rate of 992 kbit/s, so that the linecode of this prototype modem is probably uncoded PAM16.
The actual performance of this prototype modem is irrelevant for this experiment. The aim of this experiment is to observe the ***decrease*** in modem performance when ingress noise is additionaly injected to the line, on top of the crosstalk noise.

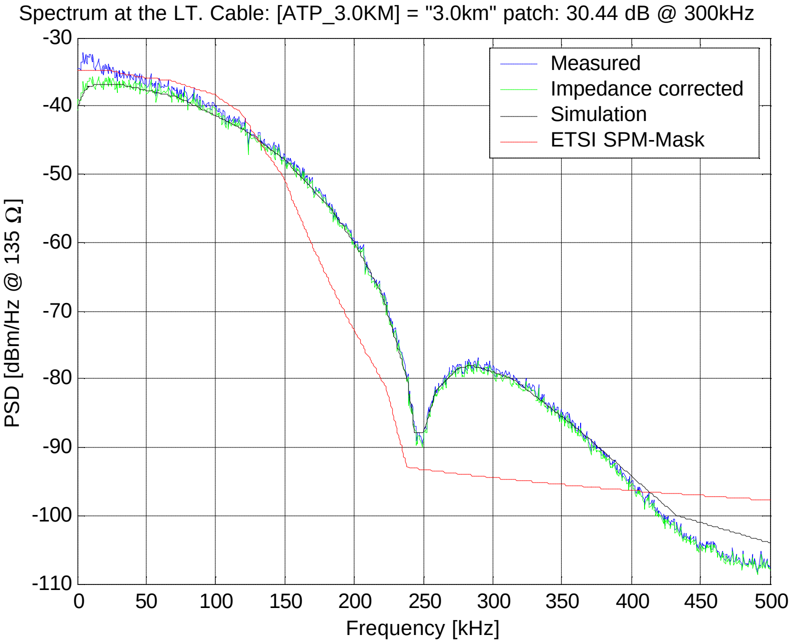

Figure 1. *Measured PSD of the prototype SDSL look alike modem under test, as it can be observed at the LT-side of the line.*

2.2. Test setup

The modem under test was stressed with noise and a testloop, in a way that is in line with the ETSI performance tests but not fully ETSI compliant. The setup is shown in figure 2.
Both the crosstalk and ingress noise were synthesized simultaneously using a technology developed within KPN Research. The impairment generator in figure 2 generates therefore the superposition of noise with a user definable continuous spectrum (crosstalk noise) as well as noise with a user definable discrete spectrum (ingress noise). This technology enabled arbitrarly shaped noise and an arbitrarly number of randomly AM-modulated RFI tones [3], each with an individual modulation width and depth.
The testloop is created with 0.5mm cables (type "KPN_L4" [4]), about 3 km long.

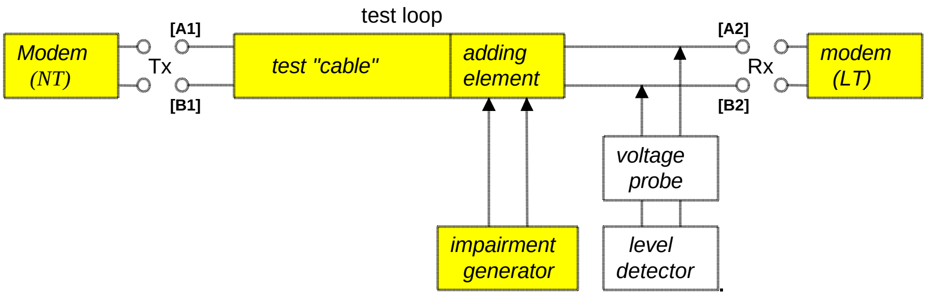

Figure 2*. Test Setup*

2.3. Generated crosstalk noise

The crosstalk noise used in this experiment is based on noise model "B" of ETSI SDSL, with some modifications.

- The alien noise follows exactly the ETSI standard, but is evaluated for 3 km "KPN_L4" cable [4].
- The self noise was based on the measured PSD of the modem under test (see figure 1), by adding 11.7 dB. This is not perfectly in line with the ETSI SDSL standard, but the rationale behind it is the same.

The crosstalk noise was kept the same during the experiment; the modem under test was trained while this crosstalk noise was activated.

2.4. Generated ingress noise

The ingress noise was constructed from 10 individual RFI tones, and each of them was AM modulated with random noise causing 10 kHz modulation width and 0.32 modulation depth [3]. There was no particular preference for any particular scheme of tones, so one of the proposals (WD12 from Montreux) on RFI tones was chosen, and summarized in table 1.
This experiment was restriced to injecting differential mode ingress noise only; no common mode ingress noise.

Frequency (kHz)	99	207	333	387	531	603	711	801	909	981
Power diff (dBm)	-70	-50	-60	-60	-40	-60	-60	-40	-70	-40

Table 1 *RFI ingress noise for SDSL and ADSL according to WD 12 from Montreux*

Due to the fact that the modem under test is a fixed bitrate modem only, it was not possible to study the impact of ingress noise at the highest SDSL bitrate of 2.3 Mb/s. To cope with this, the opposite approach was followed. In stead of stretching the spectrum of the modem from a symbol rate of 248 kbaud to 771 kbaud (for transporting 2.3 Mb/s), the spectrum of RFI tones was compressed. This resulted in the modified RFI tones as shown in table 2.
It is assumed that impairing this prototype modem under test with the RFI tones in table 2 is indicative for what will happen when an 2.3 MB/s SDSL modem is stressed by the RFI tones in table 1.

Frequency (kHz)	32	67	108	126	172	196	231	260	295	319
Power diff (dBm)	-70	-50	-60	-60	-40	-60	-60	-40	-70	-40

Table 2 *modified RFI ingress noise, for simulating the impact on 2.3 Mb/s modems*

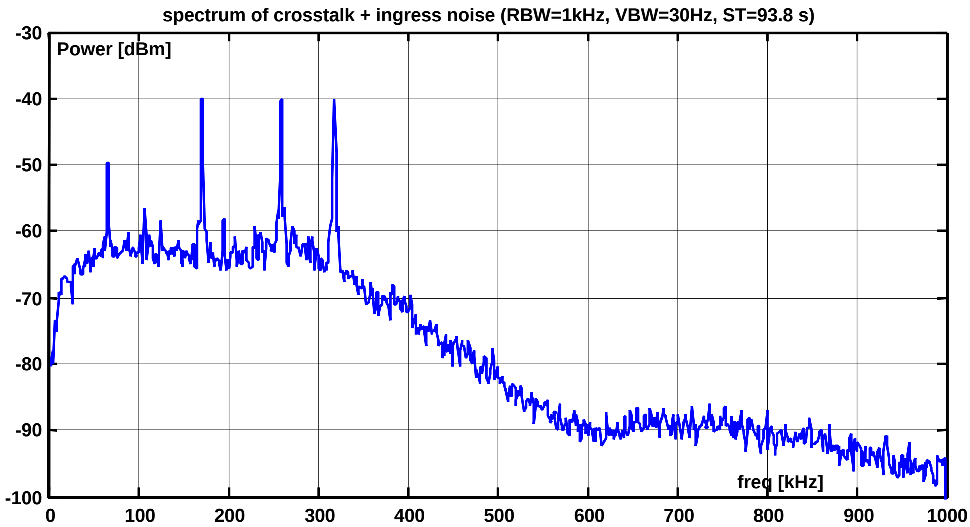

Figure 3. Example spectrum of the combination of crosstalk and ingress noise

2.5 Noise margin

The prototype SDSL modem under test was trained under the above described crosstalk noise conditions, without ingress noise. Then the level of the total impairment (crosstalk + ingress noise) was raised by "x" dB, until the "sync-loss" level of the modem was reached (indicated by the modem). This sync-loss differs from the real 0 dB margin level, since at 0 dB noise margin the transmission should still have a quality of BER=10^{-7}. The sync-loss level is probably about 2-3 dB away from the 0 dB margin level.
For reasons of symplicity the noise margin was observed, compared to this sync-loss level, since this experiment is focussed only on a *relative* change in noise margin, not its absolute level.
Under the above described test conditions, with crosstalk noise only, the "noise margin" of the modem under test was about 7 dB.

3. Preliminary measurement results

Table 3 shows the observed noise margins under various test conditions.

- Scenario 1 is the starting position with crosstalk noise only.
- Scenario 2 is the same as 1, except that RFI noise is injected. The decrease in noise margin is about 1 dB.
- Scenario 3 is the same as 1, except that RFI noise is injected, modified according to table 2. If this approach is indicative for the impact of ingress noise to 2.3 Mb/s SDSL modems, then the reduction of noise margin is no more than 2 dB, compared to scenario 1.
- Scenario 4 is the same as 3, except that all RFI tones are amplified by 5 dB. Even under these severe conditions, the noise margin reduction is no more then 4 dB, compared to scenario 1.

Scenario number	Scenario description	Power Xtalk (dBm)	Power RFI (dBm)	Power Total (dBm)	Power xtalk up to $0.5 \times F_{sym}$ (dBm)	Power RFI up to $0.5 \times F_{sym}$ (dBm)	Power Total At $0.5 \times F_{sym}$ (dBm)	Noise Marge (dB) +/- 1 dB
1	Cross talk	-37.85	-	-37.85	-42.81	-	-42.81	7
2	Cross talk + RFI noise table 1	-37.85	-34.82	-33.05	-42.81	-69.0	-42.75	6
3	Cross talk + RFI noise table 2	37.85	-34.58	-32.88	-42.81	-48.82	-41.85	5
4	Cross talk + RFI noise table 2 5 db amplified	37.85	-29.68	-29.09	-42.81	-43.92	-39.93	3

Table 3. Observed noise margin and power levels

Table 3 also shows the measured powers of the impairment into 135 Ω. Since SDSL is a base band system with low-pass filters at the input, it is irrelevant what the power is of noise outside this baseband. More relevant is the total noise power from DC up to half the symbol rate Fsym= 248 kHz, since these frequency components are the most disturbing ones. Therefore the crosstalk noise power, the ingress noiose power and their sum in a frequency band from DC up to ½×248 kHz has been evaluated as well.
The change in the total baseband noise power in the grayed column is close to the change in noise margin. This observation can be used are ***rule of thumb*** to predict the noise margin reduction for scenarios that have not been measured.

4. Conclusions and recommendations

The use of worst case RFI tones up to -40 dBm for performance testing is currently controversal within ETSI-TM6, since a dramatic reduction in performance is expected.
It has been demonstrated by experiment that applying these worst case signal have some impact on the overall performance but not in a dramatic way.

Therefore it is ***recommended***:

- to accept a worst case ingress noise test with RFI tones up to -40 dBm.
- to do some experiments with the reduction of noise margin (or preferably with reach), when ingress noise is injected on top of the crosstalk noise.
- to include a few additional tests to the SDSL standard with ingress noise on top of crosstalk noise, in which some reduction in reach is allowed.

It is plausible that the increase in total noise power (up to half the symbol rate) due to injecting ingress noise is indicative for the decrease in noise margin (rule of thumb).

5. References

[1] Rob van den **Brink**, KPN, *Laboratory performance tests for xDSL systems*, ETSI-TM6 permanent documents TM6(98)10, revision 5, (980p10a5), Sophia Antipolis, Feb 2001.
[2] Kevin T **Foster**, BT, *Example RFI Ingress Measurements*, ETSI-TM6 contribution TD26 (004t26), Monterey, Nov 2000.
[3] Rob van den **Brink**, KPN, *Text proposal for modulating the Ingress noise generator,* ETSI-TM6 contribution TD4 (011t04a0), Sophia Antipolis, feb 2001.
[4] Rob.F.M. van den Brink. *Cable Reference Models for Simulating Metallic Access Networks*, ETSI STC TM6 document, TM6(97)02, revision 3, June 1998.