TITLE **Addition of UPBO specifications to "VDSL2-NL1 and VDSL2-NL2" signal descriptions**

PROJECT SpM-1 (new study points, in addition to SP 1-1 and 1-2)

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STATUS for decision, and inclusion into SpM-1

ABSTRACT[1] This contribution elaborates on the inclusion of Upstream Power Back-Off (UPBO) in spectral management descriptions of VDSL2 signals. The proposed description method has the advantage that it is independent from the UPBO implementation in VDSL2 modems and independent from the loop characteristics. Values for VDSL2_NL1 and VDSL2_NL2 have been elaborated for inclusion into the SpM-1 document (ETSI TR 101 830-1).

1 Status of the VDSL2-NL1 and VDSL2-NL2 signal descriptions

The purpose of including signal descriptions in the SpM-1 document is to assist various national authorities involved with granting access to copper loops. If they see a need for access rules in their countries, the SpM-1 document can assist them with technical correct and meaningful spectral management descriptions of signals. If not needed, or if inadequate, they can simply ignore the signal descriptions in SpM-1. ETSI will by no means impose anybody to make use of these limits. Using it is purely an issue of national concern and national regulation.

The planned deployments for VDSL2 raised the need for additional signal descriptions. In previous contributions ([4,5]) KPN/TNO proposed a spectral management description for shaped VDSL2 signals for use in the Netherlands over POTS and ISDN. More recently, BT proposed in [6] a similar signal description, but dedicated for use in UK. Since all these spectral management descriptions are assumed to be country-specific, other operators were invited to contribute VDSL2 signal descriptions that are suitable for their countries.
Currently the two NL-signal descriptions were agreed, and the UK signal description is under study [7].

The additional need for upstream power back-off (UPBO) requirements in those spectral management descriptions was foreseen, and explicitly left for further study. UPBO is an essential capability of VDSL2, to prevent that upstream capacity can only be offered to end-users nearby a cabinet, leaving hardly any capacity for end-users that are more remotely located from the cabinet. Such a feature can only be effective if it is activated on all deployed VDSL2 modems, and therefore it is essential that the details on UPBO are included in a spectral management description of VDSL2 signals.

In this contribution, we propose a solution to include UPBO in spectral management descriptions of VDSL2 signals, in a way that is *independent* from modem implementations and loop characteristics. The methodology is applicable for all VDSL2 descriptions, but the proposed numbers are elaborated for the Dutch situation. We propose to include these additions to the SpM-1 document. We continue in inviting operators from other countries to contribute similar limits, tailored to their own needs, and also for inclusion in SpM-1.

[1] **The scientific work behind this contribution has also been funded by MUSE, a European consortium of vendors, operators and knowledge institutes, cooperating within the 6th framework programme of the European Commission.**

2 The technical solution for UPBO in VDSL2 signal descriptions

2.1 The need for upstream power back-off in SpM descriptions

It is a common practice in performance studies to assume that all systems deployed from the central office (LT side) are also co-located at the customer premises (NT side). If this approximation would have been applied to VDSL2 then we get a first estimation on the performance of VDSL2 in both directions. However, such an approximation may be valid for many ADSL deployments, but is inadequate for most VDSL2 deployments (due to relatively short loops). In those cases, the CP-modems are distributed along the line, as illustrated in figure 1.
When all upstream modems transmit in such a distributed topology at full power, those modems connected via longer loops are in a disadvantage, compared to the co-located case. The crosstalk from upstream modems connected via shorter loops will then dominate, causing the performance of modems connected via longer loops to be lower than would have been achieved if all loops were equally long. This effect is well known, and can be alleviated by means of adequate measures (upstream power back off – UPBO).
UPBO can level-out this disadvantage by reducing the transmit power of nearby upstream transmitters. This enables at least that transmitters at longer loops can perform similarly in a distributed topology and in a co-located topology. However this can only work when all upstream transmitters follow the same UPBO mechanism. Therefore the use of UPBO should be *mandatory* for all VDSL2 systems sharing the same cable.

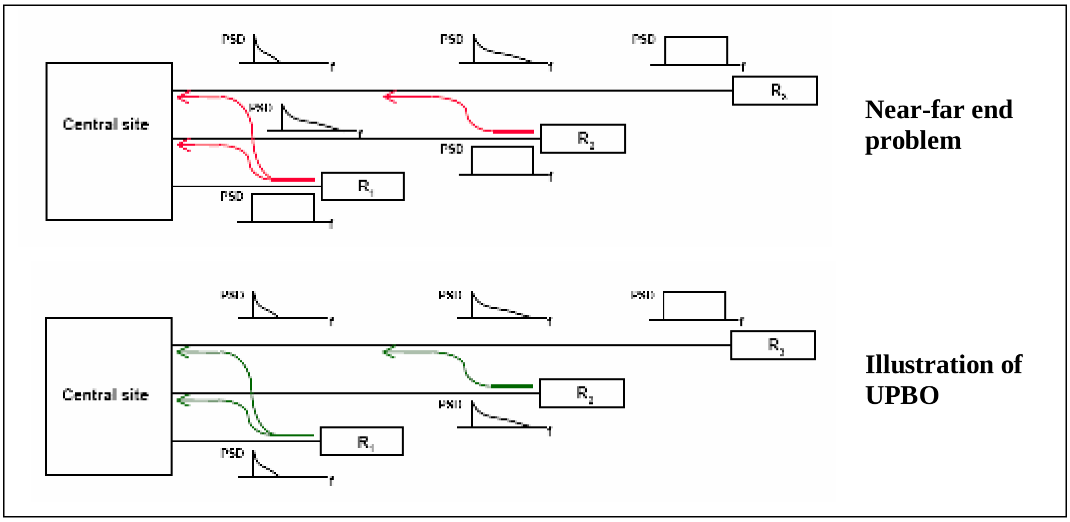

Figure 1. When CP-modems are distributed, and all upstream transmitters transmit at equal power, then the long loops are in a disadvantage.

2.2 Finding the most favorable UPBO settings

The *capability* of UPBO is well defined in the ITU VDSL2 standard [1], but this document leaves the associated settings for the individual operators. The values of the settings vary with the reference length (the maximum length up to which UPBO is required), with the loop characteristics and with the noise environment. Therefore these settings are country specific.

We analyzed various parameter values for UPBO settings, to find the "optimal" values for the Netherlands. At a first glance it would be attractive to aim for UPBO parameter values that bring so many enhancements to longer loops (at the cost of bitrates in shorter loops), that the available bitrate becomes almost equal for all loop lengths. However, beyond some point the (small) enhancements for longer loops do not justify the significant penalties in bitrate for shorter loops, so this aim will not result in an "optimum".
As an alternative, we found a pragmatic "optimum" by aiming for UPBO settings that causes all upstream systems to perform similarly in distributed topologies (with UPBO) and in co-located topologies (without UPBO). In other words: aiming for a length-bitrate curve (in a distributed topology) that is almost equal to a length-bitrate curve for an equivalent co-located topology.

When aiming this for 90% of the customer locations in the Netherlands (<1km), we found preferred values for the involved UPBO parameters.

2.3 How to make UPBO descriptions implementation-independent?

The problem with the above mentioned preferred UPBO parameter values is that they are fully tailored to a specific modem implementation. Another modem implementation may require (slightly) different UPBO setting to achieve the same result:

- An example is the way a specific VDSL2 implementation estimates the insertion loss. We are aware of modems doing that at 1 MHz, and other modems doing that at 3.75 MHz, since the ITU standard does not describe unambiguously how to estimate that.
- More fundamentally, the preferred UPBO values for VDSL2 are meaningless when non-VDSL2 systems (that comply their spectra with the VDSL2 limits) are implementing UPBO in a very different way.

In addition, *policing* of UPBO in unbundled loops will be troubled significantly since the policing requires knowledge of the (unknown) loop insertion loss as well.
Therefore, the specification of an access rule should be expressed in an implementation independent way, without the need for specifying any of the UPBO parameter values summarized in ITU G.993.2 and G.997.

We found a solution for this by specifying limits for upstream signal levels at both the *transmit* side and the *receive* side of the upstream link. This means that the modem-pair should make its own judgement on how much power back-off is required to facilitate that the upstream signal, received at the other end of the loop, does not exceed a level that is common for all upstream links in the same cable. To specify spectral limits at the receive side is essentially to specify the reference PSD (called PSD_{REF} in ETSI, and UPBOPSD in ITU).

This feasibility of this alternative approach has been verified by means of an experiment with a VDSL2 modem pair for various loop lengths. Figure 2 and 3 illustrate what spectra have been observed at both ends of a 335m loop (0.5mm, common for the Netherlands).
Figure 2 shows the NT side of the loop, as well as the transmit limits for upstream (in 10 kHz). The actual transmit level is significantly lower (30-35 dB in this example) to make the level of the receive signal at the other side low enough. Figure 3 shows the LT side of the loop, as well as the receive limits for upstream (also in 10 kHz). It illustrates that the power back-off was adequate to bring the received signal roughly 3.5 dB below the receive limits. Similar results have been observed for other loop lengths, showing that our alternative approach works in practice.
On the bases of this result, we came to a signal description as proposed in the succeeding chapter.

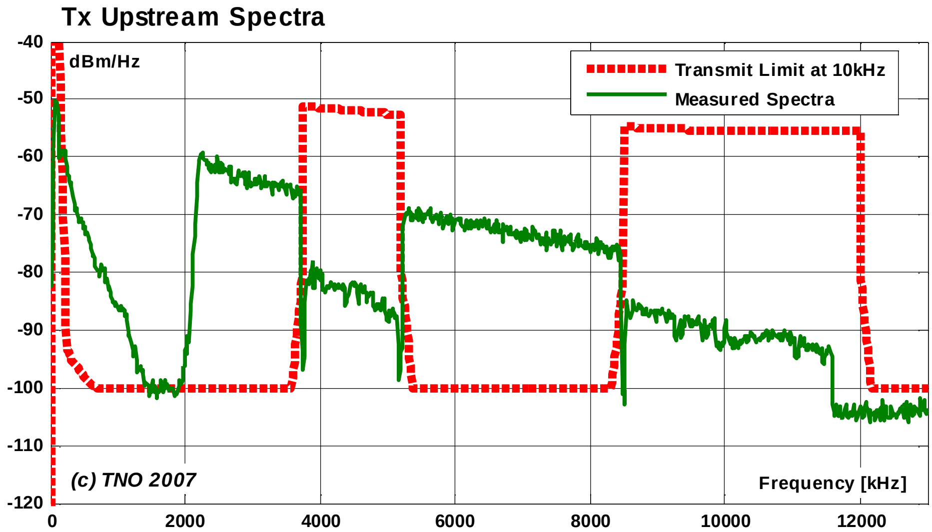

Figure 2. Spectrum measured at the NT side of the loop (at CP) when the modem applies the preferred amount of upstream power back-off.

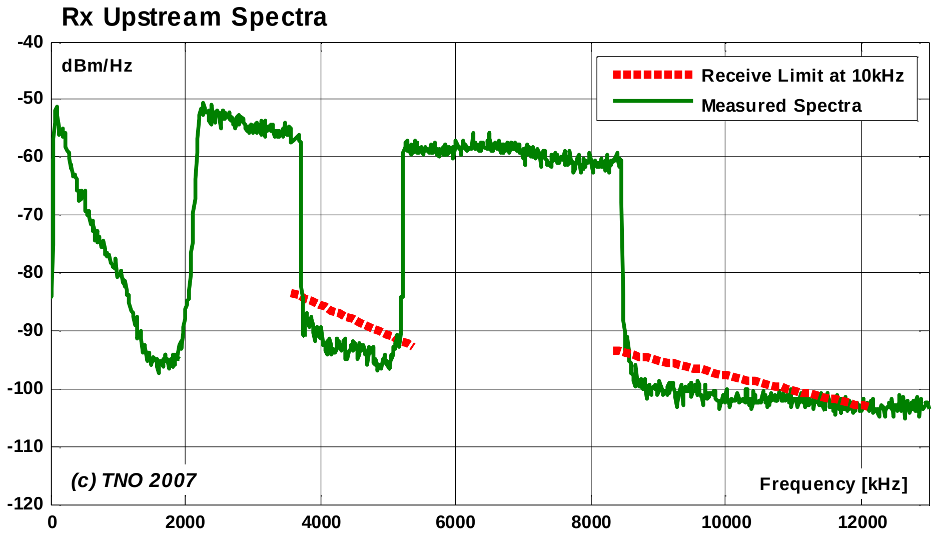

Figure 3. Spectrum measured at the LT side of the loop (at Cabinet) when the modem applies the preferred amount of upstream power back-off.

3 Literal text proposal

We propose to replace the description of the upstream limits for VDSL2_NL1 and VDSL2_NL2 by the literal text below. The UPBO additions to both variants are the same. Only the tables with transmit limits are different, but they have been contributed before and were already agreed by TM6 (and incorporated in the living list). These numbers have been omitted from table 1 for reasons of simplicity. In addition, two values in table 1 have been updated to follow recent modifications in ITU 993.2. All these changes are highlighted in blue.

START OF LITERAL TEXT PROPOSAL

ED NOTE **X.Y** refer to the paragraph numbers of the clauses describing the VDSL2-NL1 and the VDSL2_NL2 signal limits

X.Y.5 Narrow-band signal power (upstream only)

To be compliant with this signal category, the upstream signal shall comply *simultaneously* with *transmit limits*, dedicated to the upstream transmit signal observed at the NT-port of the sub loop wiring, and *receive limits*, dedicated to the upstream receive signal observed at the LT-port of the local loop wiring.
The transmit limits are worst-case limits only, and the level of the transmitted in-band frequencies should often be reduced to comply simultaneously with the receive limits. The receive limits are concentrating on in-band frequencies mainly, and the insertion loss of the sub loop wiring determines how much the upstream transmitter should reduce it's transmit level to comply with the receive limits as well. This mechanism is called Upstream Power Back-off, and this mechanism requires that the transmission system should have knowledge on the insertion loss between the LT and NT port of the sub loop wiring.

NOTE The way this information is to be acquired and handled is no part of the present signal description, and all methods enabling compliance with both transmit and receive limits are considered as adequate. The ITU-T recommendation 993.2 [1], describes methods on how VDSL2 equipment could estimate this insertion loss, and how this information could be handled by the system to implement the associated upstream power back-off.

To be compliant with this signal category, the *Narrow-Band Signal Power* (NBSP) of the upstream signal *transmitted* into the NT-port of the sub loop wiring shall not exceed the limits given in Table 1,

at any point of the specified frequency range. Simultaneously, the NBSP *received* from the LT-port of the sub loop wiring shall not exceed the limits given in Table 2.
The NBSP is the average power ***P*** of a signal, received into a resistive load ***R***, within a *power* band width ***B***. The measurement method of the NBSP is described in clause 13.2.

The tables 1 and 2 specify the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale below 3575 KHz and linear (Hz) - linear (dB) scale above 3575 KHz. Figure 4 and 5 illustrate these NBSP limits in a bandwidth-normalized way.

Table 1: Break points of the narrow-band power limits, of the upstream transmit signal.

Centre frequency f	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
	SAME AS	IN CURRENT	DESCRIPTION		"X"
12000 kHz	100 Ω	–15,5 dBm	10 kHz	–55,5 dBm/Hz	
	SAME AS	IN CURRENT	DESCRIPTION		
	SAME AS	IN CURRENT	DESCRIPTION		"Y"
11999,999 kHz	100 Ω	–9 dBm	100 kHz	–59 dBm/Hz	
	SAME AS	IN CURRENT	DESCRIPTION		
	SAME AS	IN CURRENT	DESCRIPTION		"Z"
EDITORIAL NOTE: Only the values highlighted in blue have been updated, to follow recent ITU changes					

Table 2: Break points of the narrow-band power limits, of the upstream receive signal.

Frequency F	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
3575 kHz	100 Ω	-43,45 dBm	10 kHz	-83,45 dBm/Hz	"X1"
…	100 Ω	interp	10 kHz	interp	
5375 kHz	100 Ω	- 52,65dBm	10 kHz	-92,65 dBm/Hz	
8325 kHz	100 Ω	-53,41 dBm	10 kHz	-93,41 dBm/Hz	"X2"
…	100 Ω	interp	10 kHz	interp	
12175 kHz	100 Ω	-63,37dBm	10 kHz	-103,37 dBm/Hz	
3575 kHz	100 Ω	-36,95 dBm	100 kHz	-86,95 dBm/Hz	"Y1"
…	100 Ω	interp	100 kHz	interp	
5375 kHz	100 Ω	-46,15dBm	100 kHz	-96,15 dBm/Hz	
8325 kHz	100 Ω	-46,91dBm	100 kHz	-96,91dBm/Hz	"Y2"
…	100 Ω	interp	100 kHz	interp	
12175 kHz	100 Ω	-56,87dBm	100 kHz	-106,87dBm/Hz	

NOTE 1: The NBSP specification in table 1 is reconstructed from the commonly used PSD specifications in [1] (similar to figure 5), and used here since it is much wider applicable. This enables a unified specification method. PSD specifications are adequate when signals are purely random in nature, but cannot cover harmonic components in a signal (would cause infinite high "PSD" levels at these harmonic frequencies). NBSP specifications cover both signal types.

NOTE 2: The NBSP specification of the upstream transmit signal (table 1) has been split into three overlapping limits: "X", "Y" and "Z". All three upper limits hold simultaneously. The 10 kHz bandwidth values represent the "maximum PSD values" from [1], and includes the pass band ripple. The 100 kHz bandwidth values represent the "average PSD values" in the pass band to smooth out the spectral ripple of 3,5 dB. The 1 MHz bandwidth specification is equivalent to the sliding window specification being common for ADSL

NOTE 3: The NBSP specification of the upstream receive signal (table 2) has been split into four overlapping limits: "X1", "X2", "Y1" and "Y2". All these limits hold simultaneously, as explained in NOTE 2.

Reference: ITU-T Recommendation G.993.2 [1], clause B2.4 reconstructed from PSD requirements.

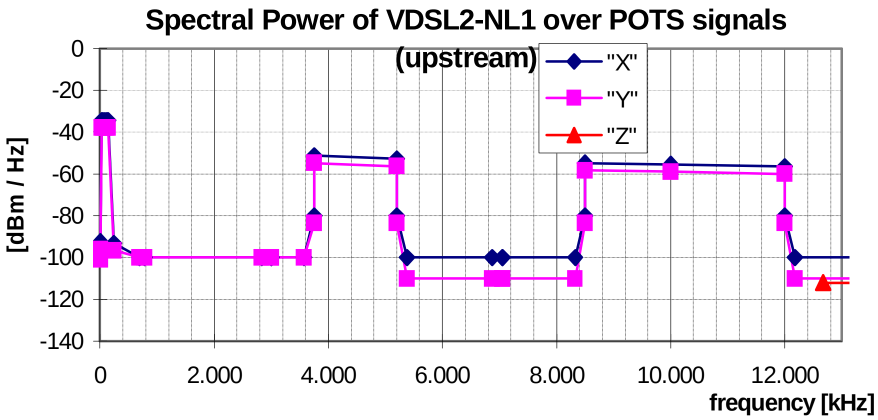

Figure 4: Spectral Power for "VDSL2-NL1" upstream *transmit* signals, as specified in table 1.

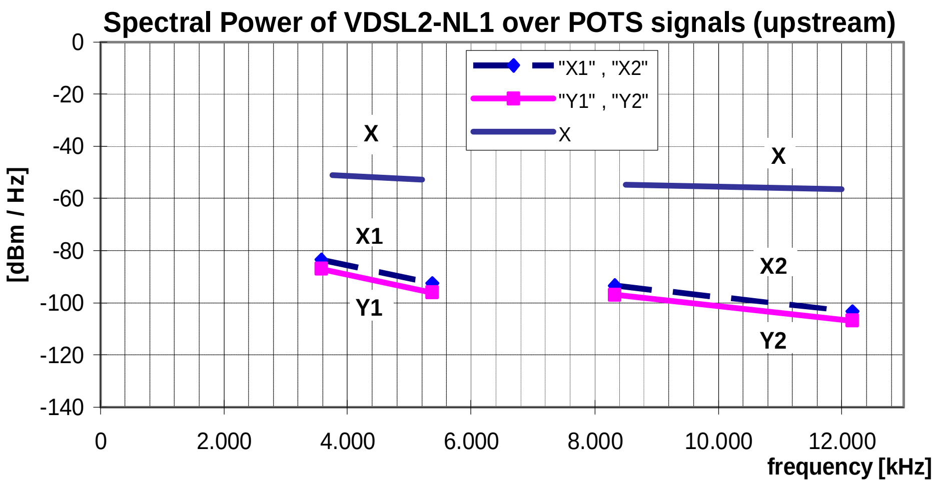

Figure 5: Spectral Power for "VDSL2-NL1" upstream *receive* signals,

END OF LITERAL TEXT PROPOSAL

4 Conclusions and proposal

In this contribution, we have elaborated a solution for adding Upstream Power Back-Off limits (UPBO) to spectral management description for VDSL2 signals.

The UPBO description in the VDSL2 product standard G993.2 is inconvenient for spectral management purposes, since it is too much tailored to a specific modem implementation. Therefore we proposed in our contribution a different approach. We specify limits for both the transmit and receive side of an upstream sub-loop, without specifying how the modem-pair should enable that. The additional advantage is that our approach is also independent from the loop characteristics (and this simplifies policing significantly!)

The elaborated values are tailored for the VDSL2_NL1 (“over POTS”) and VDSL2_NL2 (“over ISDN”) descriptions, but we believe that the methodology can be applied to all spectral management descriptions of VDSL2 signals.

This contribution incorporates literal text on how to change the upstream descriptions of VDSL2_NL1 and VDSL2_NL2. We propose to open dedicated study points to these additions, and to incorporate the revised descriptions in the planned revision of TR 101 830-1.

5 References

References being used in the literal text proposal

[1] ITU-T Recommendation G993.2: “Very High Speed Digital Subscriber Line 2 (VDSL2)”, March 2006. (Plus all amendments and corrections, including “Draft amendment 1 to Recommendation G.993.2, Feb 27, 2)

[2] ITU-T Recommendation G997.1: “Physical layer management for digital subscriber line (DSL) receivers”, June 2006.

[3] ETSI TS 101 388 (V1.3.1): "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Asymmetric Digital Subscriber Line (ADSL) - European specific requirements [ITU-T Recommendation G.992.1 modified]".

Other references

[4] ETSI 063t07, "Description of “VDSL2-NL1” signals, for spectral management purposes in the Netherlands" – TNO/KPN

[5] ETSI 064t25, "Description of “VDSL2-NL2” signals, for spectral management in the Netherlands" – TNO/KPN

[6] ETSI 072t12, "Description of “VDSL2-UK1” signals, for spectral management in the United Kingdom - BT.

[7] ETSI m06p09a03_SpM1_LL, "Living list for Spectral Management part 1”