TITLE **Algorithmic model for VDSL2 transmitters**

PROJECT SpM-2 (study point SP2-6, SP2-7 and SP2-8)

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ABSTRACT[1] This contribution presents a calculation model for the template PSD of VDSL2 transmitters. It uses an algorithmic approach based on four independent building blocks, as proposed before in 064t22. The current contribution demonstrates the feasibility of this approach by elaborating a subset of all required models. The full solution still requires only a limited number of PSD tables.

1 The need of algorithmic models for VDSL2 transmitters

To perform spectral management studies of the impact of VDSL2 to legacy xDSL systems, or of the performance of VDSL2 in a noisy environment, simulation models for VDSL2 transmitters are required. A common strategy for systems like ADSL, SDSL and HDSL is to model these transmitters by describing the nominal output spectra by means of fixed PSD templates. Part 2 of the ETSI spectral management standard [4] is a container document with all kinds of models, and the addition of VDSL2 models via fixed PSD templates have been proposed [1,3] within ETSI-TM6 for inclusion in an update of that document.
However, the number of “standard” signal spectra being defined in the ITU specification G993.2 [6] is so numerous, that a fixed approach will be very inconvenient in practice [2]. In addition, when PSD shaping is applied to VDSL2 downstream signals or power back-off to upstream signals, the number of spectra to be modelled by fixed tables becomes very challenging.

A principal solution to this problem is to make use of an *algorithmic* approach instead of a fixed on. This has been suggested before [2], and can give sufficient flexibility to control all aspects of VDSL2 spectra. However, the derivation of such a description is not obvious, due to the complexity of VDSL2 spectra. Moreover, the ITU standard gives insufficient guidance on how to do that, because it is focused on specifying the *upper limits* of spectra (PSD-masks) instead of their *nominal* value (PSD-templates).

This contribution elaborates on the algorithmic approach, as proposed in [2], and systematizes on how the PSD template should be created for VDSL2 transmitters. The result is straightforward to program in software tools for simulations. All the basic PSD templates implied with the ITU G993.2 [6] (profiles and masks) can be generated from this model in combination with the proposed parameters.
Since such a model is about PSD templates and not about PSD masks, it can take advantage of some simplification by ignoring details about the slope near a “brick wall”.

[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 Proposed algorithmic model

The complexity of VDSL2 (many flavours many kinds of PSD shaping/PBO in downstream and upstream, power restrictions) requires a break-down of the specification of a PSD template for a particular scenario. Figure 1 illustrates how the VDSL2 transmitter model is broken down into four individual building blocks. Each block has its own set of controlling parameters, to control one or more aspects of the output spectrum of VDSL2.

- A "PSD band constructor" that enables the bands requested by the user above a "*noise floor*" being defined for all frequency of interest.
- A "PSD shaper" that modifies the shape of an intermediate template PSD by a parametric formula, guided by the victim spectrum to be protected in the downstream and by the desired received signal in the upstream.
- A "PSD Notcher" that can "punch" notches in a shaped PSD, to prevent egress levels being too high in radio bands of interest.
- A "PSD power restrictor" that can modify a PSD (template) in such a way that the aggregate power of the PSD does not exceed some pre-defined upper limit.

In addition, pre-defined tables are provided for the "PSD band constructor" to generate spectra that are compliant with those being defined in the ITU specification G993.2 [6].

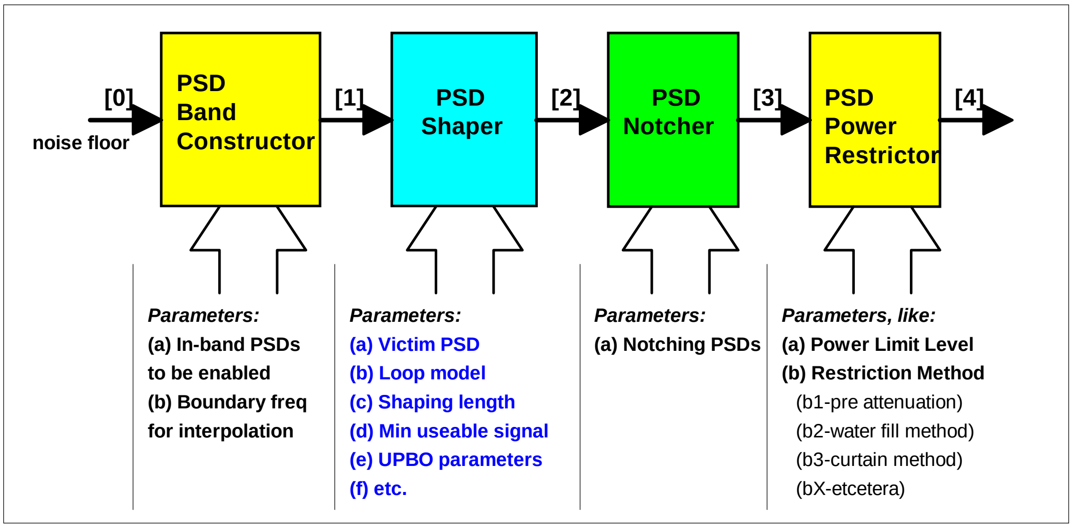

***Figure 1:** Building blocks of a VDSL2 transmitter model, for defining a wide range of PSD templates with only a few PSD tables and formulas.*

2.1 Building block #1 for "PSD Band Constructor"

Building block #1 for the "PSD band constructor" generates a static PSD template, selected from a set of spectra (in-band PSDs). Pre-defined spectra are provided by means of break point tables, up to 30 MHz, but the use of the algorithmic model is not restricted to these tables.

The model in figure 2 starts from a PSD, representing a *noise floor*, and combines it subsequently with as many in-band PSDs as required. A pre-defined noise floor is provided as well.

Combining means within this context: taking the *maximum* of two PSD levels, where one PSD is the selected in-band PSD, and the other is a PSD being built-up in previous steps (starting with the noise floor). This maximum is to be evaluated for all frequencies within the band of the selected in-band PSD. Outside that band, the PSD will remain unchanged.

Figure 3 visualizes such a step in reconstructing a resulting PSD from these two "input" PSDs.

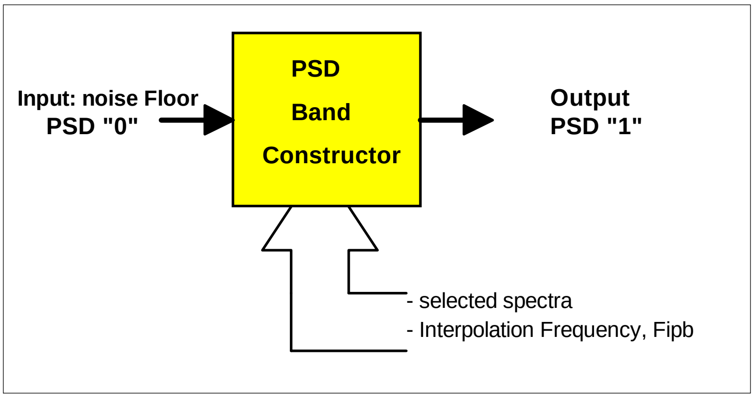

Figure 2: Conceptual description of the "PSD Band Constructor" block

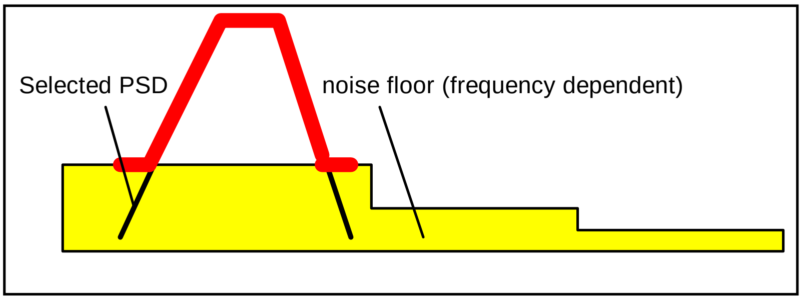

Figure 3: Illustration on how building block #1 combines two PSDs for creating a third.

The in-band PSDs can have arbitrary spectra and can be defined in many ways. A commonly used approach is a PSD definition by means of break-point tables. Such a PSD is derived via interpolation, by interconnecting the breakpoints via a straight line when plotted on a linear dB scale. This is called "linear" interpolation, when plotted on a linear frequency axis, "logarithmic" interpolation, when plotted on a logarithmic axis, and "mixed" interpolation when both methods are applied in different frequency bands. When mixed interpolation applies, the boundary frequencies are to be specified as well.

For the purpose of VDSL2 modelling pre-defined in-band spectra are provided by means of breakpoint tables, and specified in table 3 to 13 for all band plans and profiles being identified in G993.2 [6]. For all cases only one boundary frequency applies (f_{ipb}), based on the following convention:

- if $f \le f_{ipb}$ do logarithmic interpolation
- if $f > f_{ipb}$ do linear interpolation

A suitable noise floor is pre-defined in table 1, but the model is not restricted to any of these pre-defined PSDs.

Table 1: Pre-defined noise floor, derived from clause B4.1 in G993.2 [6], as starting PSD for building block #1

f [MHz]	NF1 P [dBm/Hz]
0	–100
4M	–100
4M	–110
5.1M	–110
5.1M	–112
30M	–112

2.2 Building block #2 for "PSD Shaper"

Building block #2 is typically algorithmic in nature, roughly following the way it is formulated in G997.1 [7]. A difference is that shaping is to be applied in this building block to PSD *templates* and not to PSD *masks*. The model in figure 4 provides the generic idea, but details are currently left for further study. The algorithm is expected to be rather complicated.

NOTE The details of specifying block#2 is for further study. Below are some initial thoughts on how to implement this building block

To model DPBO aspects in downstream signals, the following parameters may apply:

- The PSD template of a victim signal (level at central office) that is to be protected by proper shaping is typically an ADSL2plus downstream signal. This signal may distinct between the "annex-A" and "annex-B" variants for both the overlapping and non-overlapping spectra. This template is related to DPBO_EPSD specified in G997.1.
- A pair of (f_{min}, f_{max}) to indicate the band in which shaping is applied to the VDSL spectrum. These are typically the **DPBO_FMIN** and **DPBO_FMAX** parameters specified in G997.1.
- The loop model is another "parameter", such as for instance a polynomial curve (like the e-side cable model "**DPBO_ESCM**" used in G997.1, using parameters like A,B,C), or even more advanced models like "TP100" or "TP150" specified by ETSI as VDSL test loop.
- The shaping length can be another parameter, which can be the actual loop-length between central office and cabinet, or something shorter. This is typically the **DPBO_ESEL** parameter specified in G997.1, representing the so called "E-Side Electrical Length" (in dB).
- The minimum useable victim signal can be a fifth parameter, which can even change with the shaping length. Its value is essential to determine up to what frequency the VDSL2 PSD has to be shaped to protect the victim PSD. This is typically the **DPBO_MUS** parameter specified in G.997.1, and is called "Minimum Useable Signal".
- More parameters can be applied, when appropriate.

To model UPBO aspects in upstream signals, several methods can be used. Currently, only one method is defined in the standard, the *reference length*. However, in the future, new methods can be included and supported.

Considering the *reference length* method only, he following parameters may apply:

- The PSD template desired at the receiver side (cabinet), defined by [a,b] per band parameters.
- The frequency at which kl_0 will be evaluated (e.g. 1 MHz, 3.75 MHz, etc).
- More parameters can be applied, when appropriate.

All details are left for further study, but the concept remains the same as for downstream and its implementation is straightforward

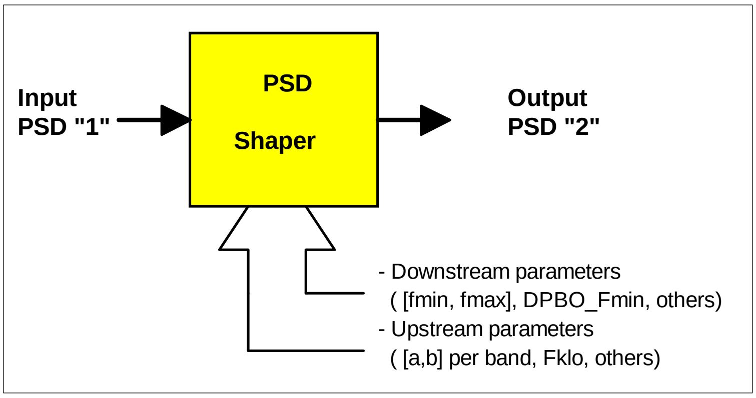

Figure 4: Conceptual description of the "PSD Shaper" block

2.3 Building block #3 for "PSD notcher"

Building block #3 enables to punch notches in the spectrum, to reduce the effect of unwanted radiated emissions from VDSL2 causing undue interference to existing licensed users of that part of the spectrum. The description of this building block is roughly the same as for building block #2 ("PSD band constructor"), but its influence on the overall PSD will be different when shaping (in block #3) has been applied. The model in figure 5 starts from an input PSD and combines it subsequently with as many notching PSDs as required.
Combining means within this context: taking the *minimum* of two PSD levels, where one PSD is the selected notching PSD, and the other is a PSD being built-up in previous steps. This minimum is to be evaluated for all frequencies within the band of the selected notching PSD. Outside that band, the PSD will remain unchanged.

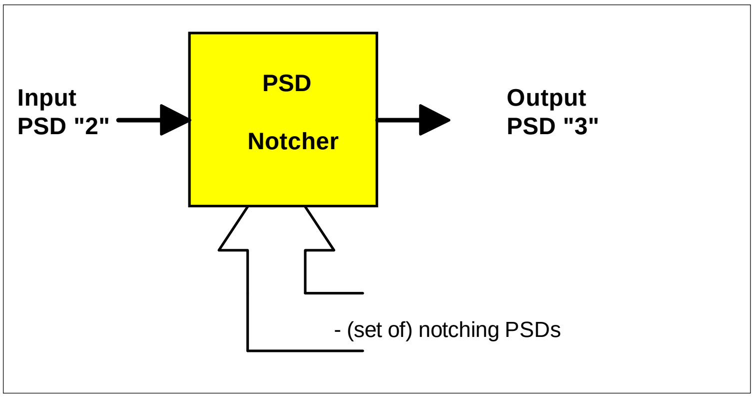

Figure 5: Conceptual description of the "PSD Notcher" block

Table 2 summarizes a set of pre-defined notching PSDs, suitable for reducing egress into internationally standardized amateur radio bands. The model is not restricted to these pre-defined notching PSDs. The numbers are taken from the ETSI VDSL1 standard [5]. If required, this notching can be repeated for multiple frequency intervals when more bands are to be notched. In that case the controlling parameter of this model is a *set* of notching PSDs.

Table 2: Break point tables of several pre-defined notching PSDs

Band to be notched	f [MHz]	P [dBm/Hz]
'NB1'	1.81 2.00	-80 -80
'NB2'	3.50 3.80	-80 -80
'NB3'	7.00 7.10	-80 -80
'NB4'	10.10 10.15	-80 -80
'NB5'	14.00 14.35	-80 -80
'NB6'	18.068 18.168	-80 -80
'NB7'	21.000 21.450	-80 -80
'NB8'	24.890 24.990	-80 -80
'NB9'	28.000 29.100	-80 -80

2.4 Building block #4 for "PSD Power Restrictor"

Building block #4 enables to cut-back the overall PSD when its aggregate power appears to be above a certain power limit. Such a cut-back is to be applied when for instance a modem implementation is

unable to generate powers beyond that limit, or when the output PSD has to be compliant with maximum values specified by the profiles from G993.2 [6].
Different modem implementations may follow different strategies to cope with power limitations, and therefore different restriction methods can be applied to this model. A few restriction methods that can ensure that the aggregate power of a modified PSD does not exceed a certain maximum value are pre-defined below, but other methods are not excluded:

- ***Attenuator method***. This power restriction requires an algorithm that causes a (frequency *in*dependent) attenuation of the full PSD. When the aggregate power of the PSD exceeds a specified limit, the algorithm is to increase this attenuation until a value that makes the aggregate power of the PSD equal to the specified limit. This method is very simple, and is often inadequate to approximate the power restriction in a real modem implementation.
- ***Water-filling method***. This power restriction requires an algorithm that clips all PSD values above a certain (frequency independent) "ceiling PSD value". When the aggregate power of the PSD exceeds a specified limit, the algorithm is to lower this "ceiling" down to a value that makes the aggregate power of the PSD equal to the specified limit. This method is typically iterative in nature but rather straightforward.
- ***Curtain method***. This power restriction requires an algorithm that replaces all PSD values up to a certain "curtain" frequency by a pre-defined (frequency independent) "floor PSD value". When the aggregate power of the PSD exceeds a specified limit, the algorithm is to raise this "curtain" frequency up to a value that makes the aggregate power of the PSD equal to the specified limit. This method is also typically iterative in nature and rather straightforward as well.

Other methods may be applied too, but have not been described here.

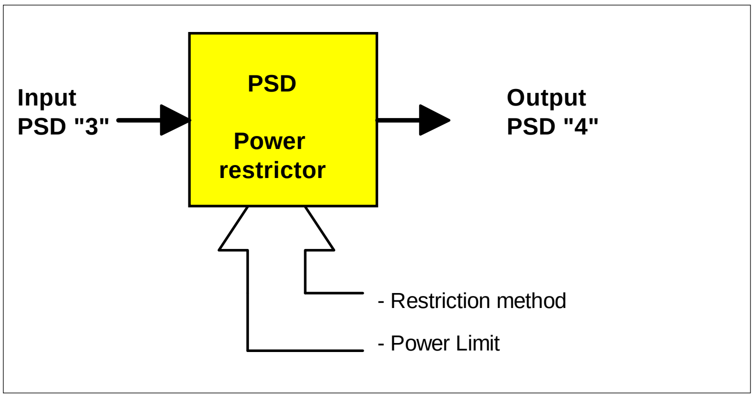

Figure 6: Input/Output Baseline PSD Power Restrictor

2.5 Pre-defined downstream tables for "PSD Band Constructor"

The PSD band constructor in building block #1 can be controlled via an arbitrary number of in-band PSDs. Pre-defined in-band PSDs for downstream transmission are summarized in table 4 to 8 and specified by means of breakpoints. Each in-band spectrum has its own (unique) identifier (summarized in table 3), for convenient referencing. A full VDSL2 transmit signal can be built-up from a proper selection of these in-band spectra. Example of meaningful combinations can be found in table [14].

The values are constructed from the breakpoints of G993.2 masks [6], roughly by correcting 3.5dB difference between mask and template for in-band frequencies, and roughly by corrected the PSD according to the constraints in 1 MHz resolution bands for out-of-band frequencies. In addition, some of the pre-defined values are adjusted via a pragmatic compromise between simplicity and ITU details.

Table 3: Summary of pre-defined in-band spectra, for downstream

downstream identifiers for in-band spectra	downstream identifiers for in-band spectra
DS.1L.a_998 DS.1L.b_998 DS.1X.r_998 DS.1X.b_998 DS.2.r_998 DS.2.b_998 DS.3.p1_998 DS.3.p2_998 DS.3.p3_998 DS.3.p4_998 DS.4.p1_998	Tables defining in-band spectra suitable for band plan 997 are left for further study

Table 4: Pre-defined in-band spectra for DS.1-legacy

	DS.1L.a_998	DS.1L.b_998
f **[Hz]**	***P*** **[dBm/Hz]**	***P*** **[dBm/Hz]**
0	-100	-100
3999	-100	-100
4000	-96	-96
80000	-76	interp
101200	interp	-96
137999	-47.7	interp
138000	-40	interp
227110	interp	-65.5
275999	interp	-52
276000	interp	-40
1104000	-40	-40
1622000	-50	-50
2208000	-51.5	-51.5

Table 5: Pre-defined in-band spectra for DS.1-extended

	DS.1X.r_998	DS.1X.b_998
f **[Hz]**	***P*** **[dBm/Hz]**	***P*** **[dBm/Hz]**
2208001	-51.5	-51.5
2249000	-53	interp
2500000	-60	interp
3749999	-60	-54.7
3750000	-83.5	-83.5
3894760	-100	-100
3999999	-100	-100
4000000	-110	-110

Table 6: Pre-defined in-band spectra for DS.2

f [Hz]	DS.2.r_998 *P* [dBm/Hz]	DS.2.b_998 *P* [dBm/Hz]
4999999	-110	-110
5000000	-112	-112
5055624	-112	-112
5055625	-100	-100
5199999	-83.5	-83.5
5200000	-60	-56.2
8499999	-60	-58.3
8500000	-83.5	-83.5
8644566	-100	-100
8644567	-112	-112

Table 7: Pre-defined in-band spectra for DS.3

f [Hz]	DS.3.p1_998 *P* [dBm/Hz]	DS.3.p2_998 *P* [dBm/Hz]	DS.3.p3_998 *P* [dBm/Hz]	DS.3.p4_998 *P* [dBm/Hz]
11825000	-112	-112	-112	-112
11855638	interp	-112	interp	-112
11855639	interp	-100	interp	-100
11999999	interp	-83.5	interp	-83.5
12000000	interp	-60	interp	-60
13855658	-112	interp	-112	interp
13855659	-100	interp	-100	interp
13999999	-83.5	interp	-83.5	interp
14000000	-60	interp	-60	interp
17664000	-60	-60	interp	interp
21000000	-83.5	-83.5	interp	interp
21372373	-100	-100	interp	interp
21372374	-112	-112	interp	interp
21449999	interp	interp	-60	interp
21450000	interp	interp	-83.5	interp
21594776	interp	interp	-100	interp
21594777	interp	interp	-112	interp
24889999	interp	interp	interp	-60
24890000	interp	interp	interp	-83.5
25034810	interp	interp	interp	-100
25034811	interp	interp	interp	-112
30000000	-112	-112	-112	-112

Table 8: Pre-defined in-band spectra for DS.4

f [Hz]	DS.4.p1_998 *P* [dBm/Hz]
12000000	-112
24745527	-112
24745528	-100
24889999	-83.5
24890000	-60
29999999	-60
30000000	-83.5
30096499	-100
30096500	-112
31000000	-112

2.6 Pre-defined upstream tables for "PSD Band Constructor"

The PSD band constructor in building block #1 can be controlled via an arbitrary number of in-band spectra. Pre-defined in-band spectra for upstream transmission are summarized in table 10 to 13 and specified by means of breakpoints. Each in-band spectrum has its own (unique) identifier (summarized in table 9), for convenient referencing. A full VDSL2 transmit signal can be built-up from a proper selection of these in-band spectra. Example of meaningful combinations can be found in table 14.

The values are constructed from the breakpoints of G993.2 masks [6], roughly by correcting 3.5dB difference between mask and template for in-band frequencies, and roughly by corrected the PSD according to the constraints in 1 MHz resolution bands for out-of-band frequencies. In addition, some of the pre-defined values are adjusted via a pragmatic compromise between simplicity and ITU details.

Table 9: Overview of pre-defined in-band spectra for upstream

Upstream identifiers for in-band spectra	Upstream identifiers for in-band spectra
US.0.p1_998 US.0.p2_998 US.0.p3_998 US.0.p4_998 US.1.r_998 US.1.b_998 US.2.r_998 US.2.b_998 US.2.x_998 US.3.p1_998 US.3.p2_998	Tables defining in-band spectra suitable for band plan 997 are left for further study

Table 10: Pre-defined in-band spectra for US.0

	US.0.p1_998	US.0.p2_998	US.0.p3_998	US.0.p4_998
f [Hz]	*P* [dBm/Hz]	*P* [dBm/Hz]	*P* [dBm/Hz]	*P* [dBm/Hz]
0	-100	-100	-100	-100
3999	-100	-100	-100	-100
4000	-96	-96	-96	-96
25875	-38	interp	-41	-96
50000	interp	-93.5	interp	-93.5
80000	interp	-85.3	interp	-85.3
120000	interp	-38	interp	-38
138000	-38	interp	interp	interp
243000	-96.7	interp	interp	interp
276000	interp	-38	-41	-38
405125	-100	interp	interp	interp
486810	interp	interp	-100	interp
501500	interp	-100	interp	-100
686000	-100	-100	-100	-100

Table 11: Pre-defined in-band spectra for US.1

f [Hz]	US.1.r_998 *P* [dBm/Hz]	US.1.b_998 *P* [dBm/Hz]
3575001	-100	-100
3605175	-100	-100
3749999	-83.5	-83.5
3750000	-60	-54.7
5199999	-60	-56.2
5200000	-83.5	-83.5
5344693	-100	-100
5344694	-112	-112

Table 12: Pre-defined in-band spectra for US.2

f [Hz]	US.2.r_998 *P* [dBm/Hz]	US.2.b_998 *P* [dBm/Hz]	US.2.x_998 *P* [dBm/Hz]
8355624	-112	-112	-112
8355625	-100	-100	-100
8499999	-83.5	-83.5	-83.5
8500000	-60	-58.3	-58.3
10000000	interp	-59	-59
11999999	-60	-59	-59
12000000	-83.5	-83.5	-60
12144761	-100	-100	interp
12144762	-112	-112	interp
13999999	interp	interp	-60
14000000	interp	interp	-83.5
14144781	interp	interp	-100
14144782	interp	interp	-112
15000000	-112	-112	-112

Table 13: Pre-defined in-band spectra for US.3

f [Hz]	US.3.p1_998 *P* [dBm/Hz]	US.3.p2_998 *P* [dBm/Hz]
21275000	-112	-112
21305249	-112	interp
21305250	-110	interp
21449999	-83.5	interp
21450000	-60	interp
24745847	interp	-112
24745848	interp	-100
24889999	-60	-83.5
24890000	-83.5	-60
25034810	-100	interp
25034811	-112	interp
29999999	interp	-60
30000000	interp	-83.5
30096499	interp	-100
30096500	interp	-112
31000000	-112	-112

2.7 Example definitions of VDSL2 transmitters

The above pre-defined break point tables enable the construction of all PSD combinations (profiles and band plans) being identified in G993.2 [6]. For example, table 14 shows a full elaboration for several ITU profiles within limiting mask “B8-4”, also known as “998-M2x-A”. In this example, shaping and notching is disabled. The profiles differ in their combination of allocated bands (within the limiting mask) and maximum power. When a VDSL2 transmitter is specified in this way, its output signal is fully defined.
Table 15 shows for each limiting masks being defined in G993.2 [6] what break-point tables can be considered when constructing the PSD for a specific profiles. A full elaboration for all possible combinations has been omitted here for sake of brevity.

Table 14: Full elaboration of the VDSL2 transmit PSD for a few profiles within limiting mask “B8-4”.

ITU profile + limiting mask	PSD Band constructor		PSD Shaper	PSD Notcher	PSD Power restrictor
8a, B8-4 (8a, 998-M2x-A)	NF1 f_{ipb} = 138 kHz	DS.1L.a_998 DS.1X.b_998 DS.2.b_998	<none>	<none>	14.5 dBm Water-fill
	NF1 f_{ipb} = 3575 kHz	US.0.p1_998 US.1.b_998	<none>	<none>	14.5 dBm Water-fill
8b, B8-4 (8b, 998-M2x-A)	NF1 f_{ipb} = 138 kHz	DS.1L.a_998 DS.1X.b_998 DS.2.b_998	<none>	<none>	20.5 dBm Water-fill
	NF1 f_{ipb} = 3575 kHz	US.0.p1_998 US.1.b_998	<none>	<none>	14.5 dBm Water-fill
8c, B8-4 (8c, 998-M2x-A)	NF1 f_{ipb} = 138 kHz	DS.1L.a_998 DS.1X.b_998 DS.2.b_998	<none>	<none>	11.5 dBm Water-fill
	NF1 f_{ipb} = 3575 kHz	US.0.p1_998 US.1.b_998	<none>	<none>	14.5 dBm Water-fill
8d, B8-4 (8d, 998-M2x-A)	NF1 f_{ipb} = 138kHz	DS.1L.a_998 DS.1X.b_998 DS.2.b_998	<none>	<none>	17.5 dBm Water-fill
	NF1 f_{ipb} = 3575 kHz	US.0.p1_998 US.1.b_998	<none>	<none>	14.5 dBm Water-fill
12a, B8-4 (12a, 998-M2x-A)	NF1 f_{ipb} = 138kHz	DS.1L.a_998 DS.1X.b_998 DS.2.b_998	<none>	<none>	14.5 dBm Water-fill
	NF1 f_{ipb} = 3575 kHz	US.0.p1_998 US.1.b_998 US.2.b_998	<none>	<none>	14.5 dBm Water-fill
12b, B8-4 (12b, 998-M2x-A)	NF1 f_{ipb} = 138kHz	DS.1L.a_998 DS.1X.b_998 DS.2.b_998	<none>	<none>	14.5 dBm Water-fill
	NF1 f_{ipb} = 3575 kHz	US.1.b_998 US.2.b_998	<none>	<none>	14.5 dBm Water-fill

Table 15: Summary of the set of break-point tables that may play a role within each limiting mask being defined in G993.2 [6].

Mask name	DS.1L.a	DS.1L.b	DS.1X.r	DS.1X.b	DS.2.r	DS.2.b	DS.3.p1	DS.3.p2	DS.3.p3	DS.3.p4	DS.4.p1		US.0.p1	US.0.p2	US.0.p3	US.0.p4	US.1.r	US.1.b	US.2.r	US.2.b	US.2.x	US.3.p1	US.3.p2
B8-1	×		×		×								×				×		×				
B8-2		×	×		×									×			×		×				
B8-3	×		×		×												×		×				
B8-4	×			×		×							×					×		×			
B8-5		×		×		×									×			×		×			
B8-6		×		×		×										×		×		×			
B8-7	×			×		×												×		×			
B8-8	×			×		×	×											×			×		
B8-9		×		×		×	×											×			×		
B8-10		×		×		×		×										×		×			
B8-11	×			×		×		×					×					×		×			
B8-12		×		×		×		×								×		×		×			
B8-13	×			×		×			×		×							×			×	×	
B8-14		×		×		×			×		×							×			×	×	
B8-15		×		×		×				×								×		×			×
B8-16	×			×		×				×								×		×			×
B7-xx	u n d e r s t u d y																						

3 Example usage of the proposed model

The effectiveness of our proposed algorithm model may be illustrated by a few examples. The examples below focus only on the first and last block of our model: the "PSD Band Constructor" and the "PSD Power Restrictor."

3.1 Example #1: Generating an upstream signal without US2

Figure 7 shows an intermediate spectrum at the output of block #1 (the "PSD band constructor") of an upstream signal that is compliant with ITU profile '8c' starting from Mask 'B8-4'. This profile is mainly characterized by the property that only the signal bands US0 and US1 are enabled, while US2 is disabled.

Figure 7 enables a comparison between the (template) PSD generated by block #1 with the PSD-mask specified in ITU G993.2 [6]. The result is in line with G993.2, and that can be summarized as follows:

- The (template) PSD is 3.5 dB below the PSD mask in frequency bands in which the PSD is above –96.5 dBm/Hz (as specified in clause B.4.1 of G993.2 [6])
- The (template) PSD is set to –100 dBm/Hz below 4 MHz, and –112 dBm/Hz above 5 MHz (as specified in clause B.4.1 of G993.2 [6]).

The aggregate power of this signal does not exceed the limits specified by profile "8c", and therefore block #4 (the "Power restrictor") does not modify the intermediate spectrum. This is demonstrated by the curve in figure 8, which is equal to the curve in figure 7.

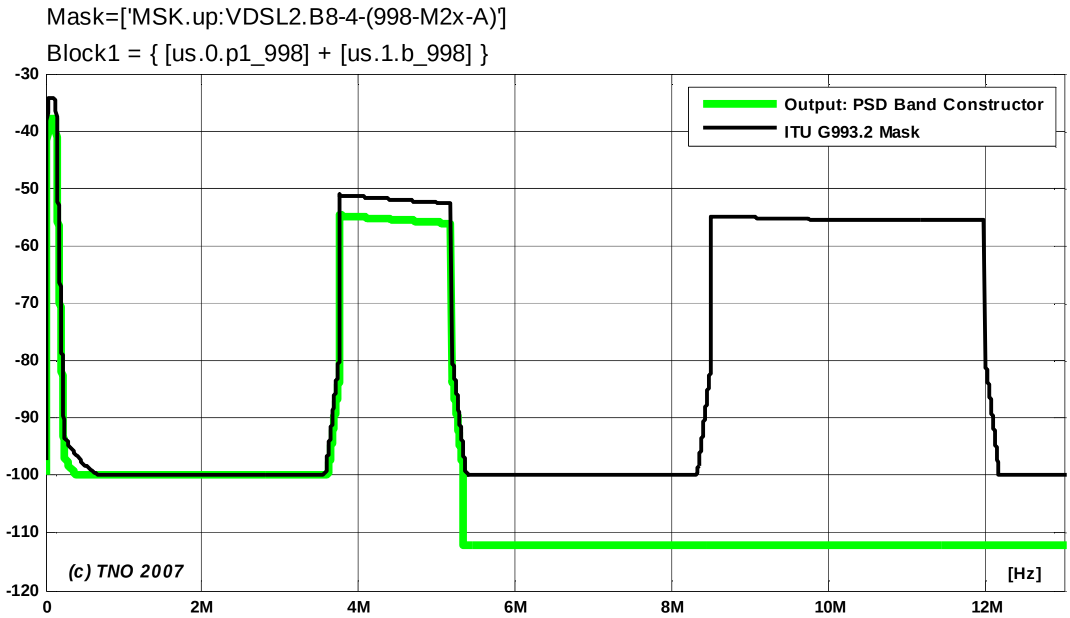

Figure 7: Intermediate spectrum at the output of block #1, while generating ITU profile “8c” from mask “B8-4” for upstream.

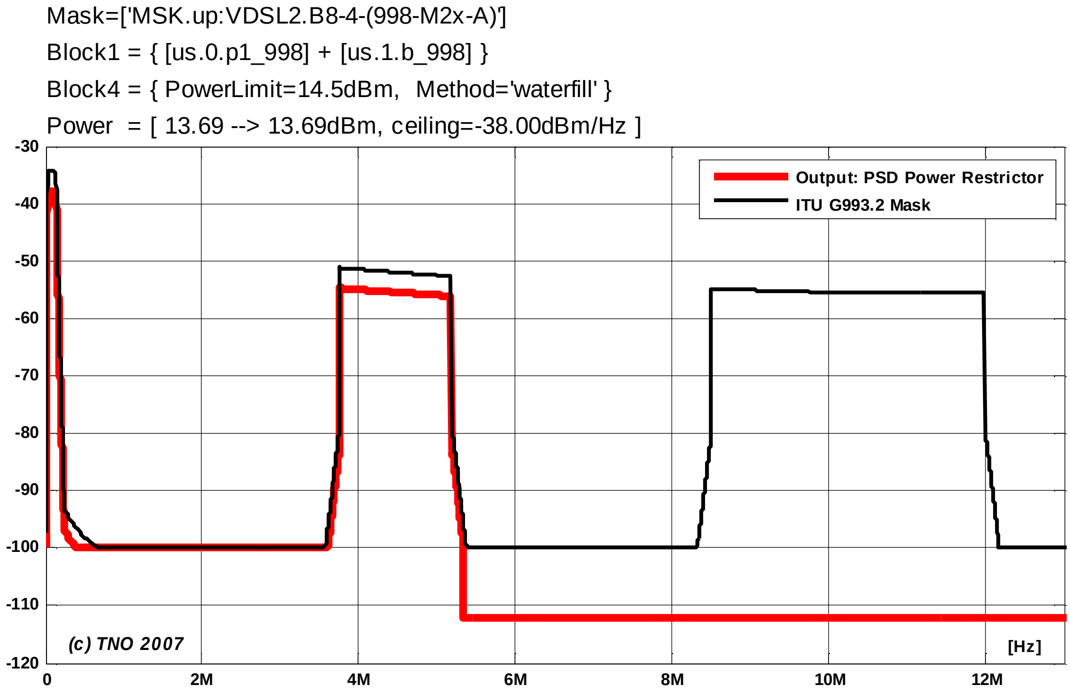

Figure 8: Output spectrum (at the output of block#4), while generating ITU profile “8c” from mask “B8-4” for upstream.

3.2 Example #2: Generating a downstream signal with power restrictions

Figure 9 shows an intermediate spectrum at the output of block #1 (the "PSD band constructor") of a downstream signal that is compliant with the same ITU profile '8c' starting from Mask 'B8-4'. One of the characteristics of this profile is that the power is restricted to 11.5 dBm.

Figure 9 enables a comparison between the (template) PSD generated by block #1 with the PSD-mask specified in ITU G993.2 [6]. Again, the result is in line with G993.2:

- The (template) PSD is 3.5 dB below the PSD mask in frequency bands in which the PSD is above –96.5 dBm/Hz (as specified in clause B.4.1 of G993.2 [6])
- The (template) PSD is set to –110 dBm/Hz between 4 and 5 MHz, and –112 dBm/Hz above 5 MHz (as specified with clause B.4.1 of G993.2 [6]).

The aggregate power of this signal exceeds the limits specified by profile "8c", and therefore the signal processing in block #4 (the "Power restrictor") has a significant impact on the spectrum: The spectrum in the DS1 band is flattened by the water-fill algorithm, in order to meet this power requirement. This is demonstrated by the curve in figure 10.

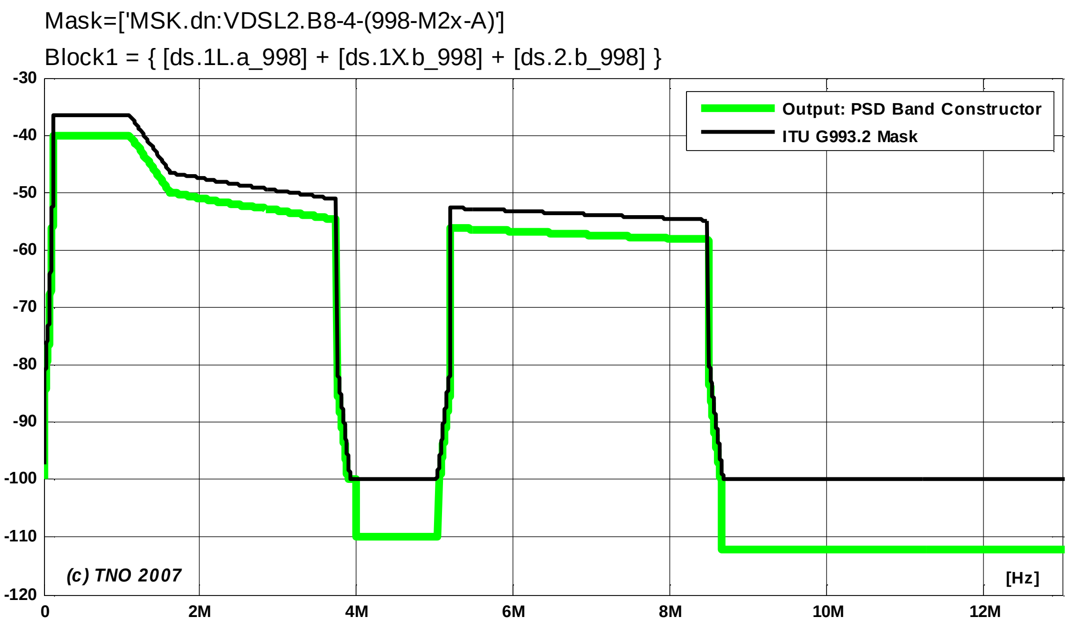

Figure 9: Intermediate spectrum at the output of block #1, while generating ITU profile "8c" from mask "B8-4" for downstream.

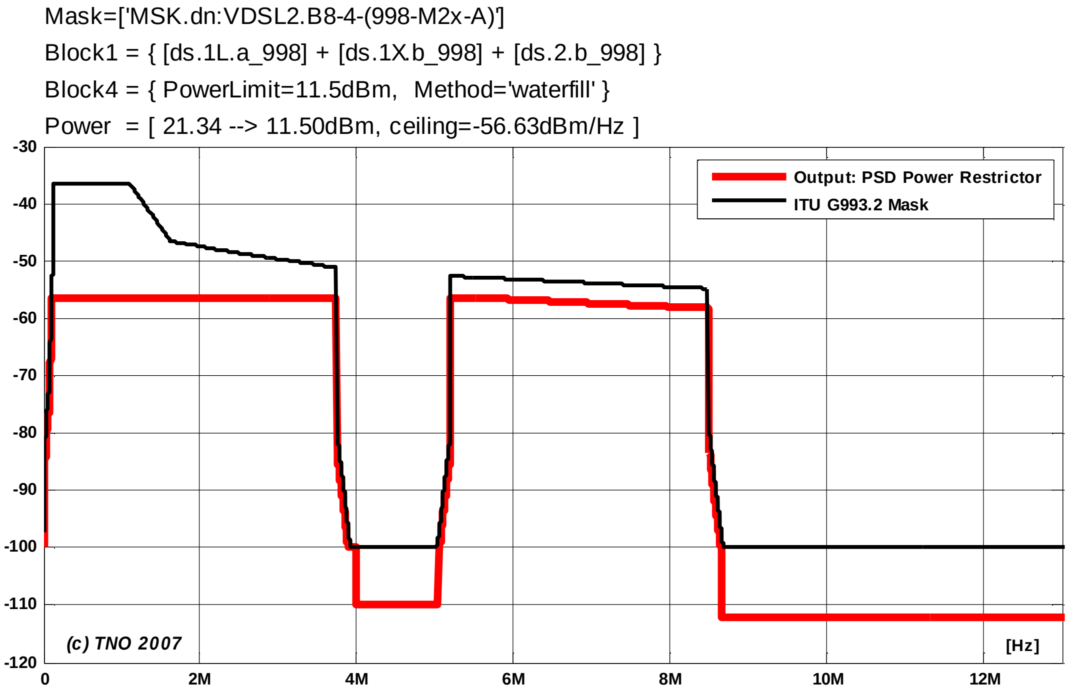

Figure 10: Downstream spectrum (at the output of block#4), while generating ITU profile "8c" from mask "B8-4" for downstream.

4 Conclusions and proposal

Specifying models for DSL transmitters by means of fixed PSD template tables was successful for modelling systems like ADSL and SDSL, but is not favourable for VDSL2. Such an approach would easily result in an exploding number of tables when all VDSL2 variants from ITU G993.2 [6] are to be combined with downstream power back-off (PSD shaping), upstream power back-off and notching. In this contribution, we elaborated on an algorithmic approach, as proposed before in 2.
We demonstrated that our algorithmic approach is flexible enough to model all VDSL2 variants from ITU G993.2 [6] by means of a limited number of tables. ***Therefore we propose to agree on the text of this contribution, for inclusion in the planned revision of the SpM2 standard [4].***

Details related to band plan 997 have not been elaborated, and are left for further study, and the same applies for the details related to PSD shaping. Therefore we also propose to add dedicated study points to the living lists of SpM2, so that agreements on the proposed text can be achieved independently from the additional text.

- ***Adding band plan 997 into the VDSL2 transmitter model***
- ***Adding downstream PSD shaping to the VDSL2 transmitter model***
- ***Adding upstream power back-off to the VDSL2 transmitter model***

5 References

[1] Andreas Thöny, Philippe Repond, *Text proposal on 998 VDSL2 PSD Templates for profiles 8b, 12a and 17a*, Swisscom, ETSI TM6 contribution 063t11, sept 2006.
[2] R.F.M van den Brink, B. van den Heuvel and T. van der Veen "Algorithmic approach for defining VDSL2 PSD templates for simulation purposes", ETSI TM6 contribution 064t22, nov 2006.
[3] Andreas Thöny, Philippe Repond, Text proposal on 998 VDSL2 PSD Templates for profiles 8b, 12a and 17a, Swisscom, ETSI TM6 contribution 064t27, nov 2006.
[4] ETSI TR 101 830-2 " Transmission and Multiplexing (TM); Access networks; Spectral management on metallic access networks; Part 2: Technical methods for performance evaluations V1.1.1, Oct 2005.

[5] ETSI TS 101 270-1 (V1.3.1): "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very high speed Digital Subscriber Line (VDSL); Part 1: Functional requirements".
[6] ITU-T Recommendation G993.2: “Very High Speed Digital Subscriber Line 2 (VDSL2)”, March 2006.
[7] ITU-T Recommendation G997.1: “Physical layer management for digital subscriber line (DSL) receivers”, june 2006.