ETSI WG TM6

(ACCESS TRANSMISSION SYSTEMS ON METALLIC CABLES)

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Living List for Spectral Management SpM - part 1 revision of TR 101 830-1

This document is the living list of current issues connected with ETSI's spectral management report TR 101 830, part 1 (*Definitions and signal library*).
This work item is focussed on the revision of "Part 1", to add new signal descriptions suitable for VDSL2 in the subloop (with PSD shaping). A target date for "working group approval" is currently scheduled for ***Feb 2008***. The issues related to revising "Part 2" are beyond the scope of this living list.

Why adding *dedicated* VDSL2 signals? The VDSL2 signal descriptions in G993.2, combined with shaping mechanisms in G997.1, enable an infinite number of PSD masks (different bandplans, many profiles, parametric definition of PSD shaping, presence of notching, etc). This facilitates very flexible VDSL2 products, but is far too complex to be helpful for defining what signal limits are allowed in cables within various countries. It would require an advanced simulation tool to find out what the actual limits are.
The SpM-1 document can fill-in this gap by offering a library with a finite number of dedicated VDSL2 signal descriptions that are tailored to specific applications; at least those that are made available for usage within a European country. Since all of SpM-1 is *informative* in nature, ETSI does not impose anybody to make use of one of these descriptions. Using it is purely an issue of *national concern* and *national regulation.* However, many European players have an interest that such signal descriptions are technically correct and unambiguous.

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2. STUDY POINTS PART 1(LIBRARY OF SIGNALS)

SP	Title	Owner	Status
1-1	Descriptions for “VDSL2-NL1” signals (“over POTS”)	Rob van den Brink (KPN/TNO)	Agreed
1-2	Descriptions for “VDSL2-NL2” signals (“over ISDN”)	Rob van den Brink (KPN/TNO)	Agreed
1-3	Descriptions for “VDSL2-UK1” signals	John MacDonald (BT)	Prov Agreed
1-4	Adding UBPO to the “VDSL2_NL” signal descriptions	Rob van den Brink (KPN/TNO)	Prov Agreed
1-5			
1-6			
1-7			
1-8			

The current agreed procedure for changing the status of living list items is in Annex A of TM6 working methods.

Part 1 study points

SP 1-1. Description for “VDSL2-NL1” signals (“over POTS”)
This study point is dedicated to a technically correct description of the VDSL2 signals being allowed in the Netherlands, which may share the line with POTS signals. (See also *www.kpn-wholesale.com*, at “*documents|national|local loop services|reference offer SLU*”)

- *063t07r1, sept 2006, Description of “VDSL2-NL1” signals, for spectral management in the Netherlands – KPN/TNO*

SP 1-2. Description for “VDSL2-NL2” signals (“over ISDN”)
This study point is dedicated to a technically correct description of the VDSL2 signals being allowed in the Netherlands, which may share the line with ISDN signals. (See also *www.kpn-wholesale.com*, at “*documents|national|local loop services|reference offer SLU*”)

- *064t25, nov 2006, Description of “VDSL2-NL2” signals, for spectral management in the Netherlands – KPN/TNO*

SP 1-3. Description for “VDSL2-UK1” signals
This study point is dedicated to a technically correct description of the VDSL2 signals being allowed in the United Kingdom, compliant with the UK Access Network Frequency Paln (ANFPi3).

- *072t12, feb 2007, Description of “VDSL2-UK1” signals for spectral management in the United Kingdom – BT*
- *074t17, nov 2007, Description of “VDSL2-UK” signals for spectral management in the United Kingdom (update) - BT*

SP 1-4. Adding UPBO to “VDSL2-NL” descriptions
This study point is dedicated to add the missing paragraph on how to define upstream power backoff (UPBO) in a implementation independent way .

- *073t27r1, sep 2007, Addition of UPBO specifications to “VDSL2-NL” signal descriptions – KPN/TNO*

Text proposals, for inclusion in the revised SpM-1.

Remove all references to the existence of "part 3", since that project has been withdrawn by ETSI-TM6

1. REFERENCES

[1] ITU-T Recommendation G993.2: "Very High Speed Digital Subscriber Line 2 (VDSL2)", Pre-published, Geneva, February 2006

[2] ETSI TS 101 270-1 (V1.4.1): "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very high speed Digital Subscriber Line (VDSL); Part 1: Functional requirements".

[3] ITU-T Recommendation G.992.1: "Asymmetric digital subscriber line (ADSL) transceivers".

[4] 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]".

Some bookmarks to sections, being used in the living list:

[13.1] clause 13.1 (SecMeas_PeakAmp) on measuring Peak amplitude

[13.2] clause 13.2 (SecMeas_NBSP) on measuring Narrow Band Signal Power

[13.3] clause 13.3 (SecMeas_Unbal) on measuring Unbalance

2. SIGNAL DESCRIPTIONS

2.1. "VDSL2-NL1" signals ("over POTS")

This category covers signals up to 12 MHz, generated by VDSL2 transmission equipment using band plan 998 (limit PSD mask B8-4). These signals may share the same wire pair with POTS signals. This signal description is derived from the ITU VDSL2 recommendation [1] and accounts for Power Back-Off in both downstream (DPBO, also kown as PSD shaping) and upstream (UPBO) direction.

- The downstream signal limits are dependent on the *attenuation distance* between the local exchange and cabinet ("primary cable"), defined as the insertion loss (IL) of that loop measured at 300 kHz into a resistive load of 100 Ω. These limits are specified for a discrete number of (integer) attenuation distances. For all other attenuation distances, the downstream limits for the nearest specified IL-values apply, and not by means of interpolating the limits.
- The upstream signal limits are fixed, but defined in such a way that the actual transmit levels changes with the insertion loss between cabinet and customer premises.

A signal can be classified as a "VDSL2-NL1" signal if it is compliant with all clauses below.

2.1.1. Total signal power (downstream only)

To be compliant with this signal category, the mean downstream signal power into a resistive load of 100 Ω shall not exceed the levels given in table 1, measured within a frequency band from at least 4 kHz to 30 MHz. In the special case of VDSL2 deployment from the local exchange, the limits associated with IL=0 apply.

Reference: ITU- T Recommendation G.993.2 [1], chapter 6.

Table 1: Total downstream transmit power as function of the measured insertion loss of the loop between local exchange and cabinet.

	IL [dB @ 300 kHz]	Downstream Total signal power [dBm]		L [m]	
	0	21,28		0	
	1	20,11		101	
	2	19,02		202	
	3	18,02		303	
	4	17,09		404	
	5	16,26		506	
	6	15,51		607	
	7	14,85		708	
	8	14,27		809	
	9	13,77		910	
	10	13,37		1011	
	11	12,95		1112	
	12	12,65		1213	
	13	12,4		1315	
	14	12,2		1416	
	15	12,04		1517	
	16	11,91		1618	
	17	11,81		1719	
	18	11,73		1820	
	19	11,66		1921	
	20	11,6		2022	
	21	11,55		2123	
	22	11,52		2225	
	23	11,48		2326	
	24	11,46		2427	
	25	11,7		2528	
	26	11,91		2629	
	27	12,15		2730	
	28	12,36		2831	
	29	12,55		2932	
	30	12,7		3034	
	31	12,82		3135	
	32	12,98		3236	
	33	13,15		3337	
	34	13,32		3438	
	35	13,56		3539	
	36	13,8		3640	
	37	14,03		3741	
	38	14,36		3842	
	39	14,67		3944	
	40	14,98		4045	
	41	15,36		4146	
	42	16,07		4247	
	43	16,63		4348	
	44	17,11		4449	
	45	17,49		4550	
	>45	17,5		>4550	

NOTE 1: The IL-values are normative. The L-values are informative and represent estimated loop lengths for a commonly used Dutch cable.

NOTE 2: Current implementations of VDSL2 transmitters, compliant with [1], are not expected to be capable of generating output powers of more then 20,5 dBm.

NOTE 3: The power limit specified for IL>45 dB may be too restrictive for

VDSL2; refinement is for further study.

2.1.2. Total signal power (upstream only)

To be compliant with this signal category, the mean upstream signal power into a resistive load of 100 Ω shall not exceed a level of +14,5 dBm, measured within a frequency band from at least 4 kHz to 30 MHz. Note that this limit is an upper limit only; the actual level may be significantly lower when the additional upstream receive limits (see table 5 and figure 4) require a strong power back-off in short loops.

Reference: ITU- T Recommendation G.993.2 [1], chapter 6.

2.1.3. Peak amplitude (upstream and downstream)

To be compliant with this signal category, the nominal voltage peak of the largest signal pulse into a resistive load of 100 Ω shall not exceed a level of 19V (38 V peak-peak), measured within a frequency band from at least 100 Hz to 30 MHz. The definition and measurement method of peak amplitude is specified in clause 13.1.

2.1.4. Narrow-band signal power (downstream only)

To be compliant with this signal category, the Narrow-Band Signal Power (NBSP) into a resistive load impedance ***R*** for a given attenuation distance, shall not exceed the limits given in table 2 and 3, at any point in the frequency range 100 Hz to 30 MHz. These tables 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 2500 kHz and on a linear (Hz) - linear (dB) scale above 2500 kHz. Figure 1 and 2 illustrate the NBSP in a bandwidth-normalized way.
The NBSP is the average power ***P*** of a sending signal into a load resistance ***R***, within a *power* bandwidth ***B***. The measurement method of the NBSP is described in clause 13.2.

NOTE 1: The NBSP specification in table 2 is reconstructed from the commonly used PSD specifications in [1] (similar to figure 1), and used here since the NBSP approach 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 this signal category has been split into three overlapping limits: "X", “Y” and "Z". All these upper limits shall hold simultaneously. The 10 kHz bandwidth values represent the "peak PSD values" from [1], and include the pass band ripple. The 100 kHz bandwidth values represent the "nominal PSD values" in the passband 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 (see [4, 3]).

NOTE 3: The description of this signal characteristic is derived from “VDSL2 band plan 998” signals with PSD mask “B8-4”. Downstream PSD Shaping has been applied between 80 KHz and 2500 kHz.

Reference: ITU-T Recommendation G.993.2 [1], clause B.2.5.

Table 2: Break points of the NBSP limits, of the downstream transmit signal.

Centre frequency f	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
0,1 kHz	600 Ω	–77,5 dBm	100 Hz	–97,5 dBm/Hz	“X”
4 kHz	600 Ω	–77,5 dBm	100 Hz	–97,5 dBm/Hz	
4 kHz	100 Ω	–52,5 dBm	10 kHz	–92,5 dBm/Hz	
f_1	100 Ω	P_1 + 40 dB	10 kHz	P_1	
f_2	100 Ω	P_2 + 40 dB	10 kHz	P_2	
f_3	100 Ω	P_3 + 40 dB	10 kHz	P_3	
f_4	100 Ω	P_4 + 40 dB	10 kHz	P_4	
f_5	100 Ω	P_5 + 40 dB	10 kHz	P_5	
f_6	100 Ω	P_6 + 40 dB	10 kHz	P_6	
f_7	100 Ω	P_7 + 40 dB	10 kHz	P_7	
f_8	100 Ω	P_8 + 40 dB	10 kHz	P_8	
f_9	100 Ω	P_9 + 40 dB	10 kHz	P_9	
f_{10}	100 Ω	P_{10} + 40 dB	10 kHz	P_{10}	
f_{11}	100 Ω	P_{11} + 40 dB	10 kHz	P_{11}	
f_{12}	100 Ω	P_{12} + 40 dB	10 kHz	P_{12}	
f_{13}	100 Ω	P_{13} + 40 dB	10 kHz	P_{13}	
f_{14}	100 Ω	P_{14} + 40 dB	10 kHz	P_{14}	
2500 kHz	100 Ω	–8,8 dBm	10 kHz	–48,8 dBm/Hz	
3749,999 kHz	100 Ω	–11,2 dBm	10 kHz	–51,2 dBm/Hz	
3750 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
3925 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
4925 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
5025 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
5199,999 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
5200 kHz	100 Ω	–12,7 dBm	10 kHz	–52,7 dBm/Hz	
8499,999 kHz	100 Ω	–14,8 dBm	10 kHz	–54,8 dBm/Hz	
8500 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
8675 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
30000 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
50 kHz	100 Ω	–46 dBm	100 kHz	–96 dBm/Hz	“Y”
f_1	100 Ω	P_1 + 46,5 dB	100 kHz	P_1 –3,5 dB	
f_2	100 Ω	P_2 + 46,5 dB	100 kHz	P_2 –3,5 dB	
f_3	100 Ω	P_3 + 46,5 dB	100 kHz	P_3 –3,5 dB	
f_4	100 Ω	P_4 + 46,5 dB	100 kHz	P_4 –3,5 dB	
f_5	100 Ω	P_5 + 46,5 dB	100 kHz	P_5 –3,5 dB	
f_6	100 Ω	P_6 + 46,5 dB	100 kHz	P_6 –3,5 dB	
f_7	100 Ω	P_7 + 46,5 dB	100 kHz	P_7 –3,5 dB	
f_8	100 Ω	P_8 + 46,5 dB	100 kHz	P_8 –3,5 dB	
f_9	100 Ω	P_9 + 46,5 dB	100 kHz	P_9 –3,5 dB	
f_{10}	100 Ω	P_{10} + 46,5 dB	100 kHz	P_{10} –3,5 dB	
f_{11}	100 Ω	P_{11} + 46,5 dB	100 kHz	P_{11} –3,5 dB	
f_{12}	100 Ω	P_{12} + 46,5 dB	100 kHz	P_{12} –3,5 dB	
f_{13}	100 Ω	P_{13} + 46,5 dB	100 kHz	P_{13} –3,5 dB	
f_{14}	100 Ω	P_{14} + 46,5 dB	100 kHz	P_{14} –3,5 dB	
2500 kHz	100 Ω	–2,3 dBm	100 kHz	–52,3 dBm/Hz	
3749,999 kHz	100 Ω	–4,5 dBm	100 kHz	–54,7 dBm/Hz	
3750 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
3894 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
3999,999 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
4000 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
5055 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
5056 kHz	100 Ω	–62 dBm	100 kHz	–99,9 dBm/Hz	
5199,999 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
5200 kHz	100 Ω	–6,2 dBm	100 kHz	–56,2 dBm/Hz	
8499,999 kHz	100 Ω	–8,3 dBm	100 kHz	–58,3 dBm/Hz	
8500 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
8644 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	

Centre frequency f	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
8645 kHz 30000 kHz	100 Ω 100 Ω	–60 dBm –60 dBm	100 kHz 100 kHz	–110 dBm/Hz –110 dBm/Hz	
9145 kHz 30000 kHz	100 Ω 100 Ω	–52 dBm –52 dBm	1 MHz 1 MHz	–112 dBm/Hz –112 dBm/Hz	“Z”
Note 1: The limits between breakpoints shall be obtained by interpolation between adjacent breakpoints on a dB/ log(f) basis below 2500 kHz and on a dB/f basis above 2500 kHz Note 2: The limits “Y” between 50 kHz and 2500 kHz are 3,5 dB lower then the associated limits “X”. This may be a bit too restrictive for VDSL2 when the PSD slope in this shaping region becomes steep. Refinements for the limits at these breakpoints require further study.					

Table 3: Definition of parameter f_k and P_k (with k = 1 to 14), of the downstream NBSP limits in table 2.

IL		f_1 P_1	f_2 P_2	f_3 P_3	f_4 P_4	f_5 P_5	f_6 P_6	f_7 P_7	f_8 P_8	f_9 P_9	f_{10} P_{10}	f_{11} P_{11}	f_{12} P_{12}	f_{13} P_{13}	f_{14} P_{14}
0	f	80	137,999	138	1104	1622	2208	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	P	–72,5	–44,2	–36,5	–36,5	–46,5	–48	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1	f	80	137,999	138	600	1104	1622	2208	2211	N/A	N/A	N/A	N/A	N/A	N/A
	P	–72,5	–44,2	–37,1	–37,7	–38,2	–48,6	–50,3	–48	N/A	N/A	N/A	N/A	N/A	N/A
2	f	80	137,999	138	250	600	1104	1622	2208	2214	N/A	N/A	N/A	N/A	N/A
	P	–72,5	–44,2	–37,6	–38	–38,9	–39,8	–50,6	–52,7	–48	N/A	N/A	N/A	N/A	N/A
3	f	80	137,999	138	250	400	600	850	1104	1622	2208	2217	N/A	N/A	N/A
	P	–72,5	–44,2	–38,2	–38,8	–39,5	–40,1	–40,9	–41,5	–52,7	–55,2	–48	N/A	N/A	N/A
4	f	80	137,999	138	250	400	600	850	1104	1622	2208	2220	N/A	N/A	N/A
	P	–72,5	–44,2	–38,7	–39,5	–40,4	–41,4	–42,3	–43,2	–54,8	–57,6	–48	N/A	N/A	N/A
5	f	80	137,999	138	250	400	600	850	1104	1350	1622	2208	2223	N/A	N/A
	P	–72,5	–44,2	–39,3	–40,3	–41,4	–42,6	–43,8	–44,9	–51,1	–56,8	–60,1	–48,1	N/A	N/A
6	f	80	137,999	138	250	400	600	850	1104	1350	1622	2208	2226	N/A	N/A
	P	–72,5	–44,2	–39,8	–41,1	–42,4	–43,8	–45,2	–46,5	–52,9	–58,9	–62,5	–48,1	N/A	N/A
7	f	80	137,999	138	250	400	600	850	1104	1350	1622	2208	2229	N/A	N/A
	P	–72,5	–44,2	–40,4	–41,8	–43,4	–45	–46,7	–48,2	–54,8	–61	–65	–48,2	N/A	N/A
8	f	80	137,999	138	250	400	600	850	1104	1350	1622	2208	2232	N/A	N/A
	P	–72,5	–44,2	–41	–42,6	–44,4	–46,2	–48,1	–49,9	–56,7	–63	–67,5	–48,3	N/A	N/A
9	f	80	137,999	138	250	400	600	850	1104	1350	1622	2208	2235	N/A	N/A
	P	–72,5	–44,2	–41,5	–43,3	–45,4	–47,4	–49,6	–51,6	–58,5	–65,1	–69,9	–48,3	N/A	N/A
10	f	80	137,999	138	250	400	600	850	1104	1350	1622	2208	2239	N/A	N/A
	P	–72,5	–44,2	–42,1	–44,1	–46,4	–48,7	–51,1	–53,3	–60,5	–67,3	–72,5	–48,1	N/A	N/A
11	f	80	137,999	138	250	400	600	850	1104	1350	1622	2208	2242	N/A	N/A
	P	–72,5	–44,2	–42,7	–45	–47,5	–50,1	–52,8	–55,2	–62,6	–69,6	–75,3	–48,2	N/A	N/A
12	f	80	137,999	138	250	400	600	850	1104	1350	1622	2208	2246	N/A	N/A
	P	–72,5	–44,2	–43,4	–45,8	–48,6	–51,5	–54,4	–57,1	–64,7	–71,9	–78,1	–48,1	N/A	N/A
13	f	80	137,999	138	250	400	600	850	1104	1350	1622	2198	2208	2248	N/A
	P	–72,5	–44,2	–44	–46,7	–49,7	–52,8	–56	–58,9	–66,8	–74,2	–80,6	–80	–48,1	N/A
14	f	80	137	250	400	600	850	1104	1350	1622	2162	2208	2248	N/A	N/A
	P	–72,5	–44,6	–47,5	–50,7	–54,1	–57,6	–60,7	–68,8	–76,4	–82,9	–80	–48,1	N/A	N/A
15	f	80	136	138	250	400	600	850	1104	1350	1622	2129	2208	2248	N/A
	P	–72,5	–45,1	–45,1	–48,3	–51,8	–55,4	–59,1	–62,5	–70,7	–78,6	–85,1	–80	–48,1	N/A
16	f	80	134	138	250	400	600	850	1104	1350	1622	2097	2208	2248	N/A
	P	–72,5	–45,7	–45,7	–49,1	–52,8	–56,6	–60,6	–64,2	–72,6	–80,7	–87,2	–80	–48,1	N/A
17	f	80	133	138	250	400	600	850	1104	1350	1622	2067	2208	2248	N/A
	P	–72,5	–46,3	–46,3	–49,8	–53,8	–57,8	–62	–65,9	–74,5	–82,8	–89,2	–80	–48,1	N/A
18	f	80	131	138	250	400	600	850	1104	1350	1622	2039	2208	2248	N/A
	P	–72,5	–46,9	–46,8	–50,6	–54,7	–59	–63,5	–67,5	–76,3	–84,8	–91,1	–80	–48,1	N/A
19	f	80	130	138	250	400	600	850	1104	1350	1622	1912	2033	2208	2248
	P	–72,5	–47,3	–47,3	–51,3	–55,7	–60,2	–64,9	–69,1	–78,1	–86,7	–91,5	–91,5	–80	–48,1
20	f	80	129	138	250	400	600	850	1104	1350	1622	1782	2033	2208	2248
	P	–72,5	–47,9	–47,9	–52	–56,6	–61,3	–66,2	–70,6	–79,8	–88,7	–91,5	–91,5	–80	–48,1
21	f	80	127	138	250	400	600	850	1104	1350	1622	1673	2033	2208	2248
	P	–72,5	–48,5	–48,4	–52,7	–57,5	–62,4	–67,5	–72,2	–81,5	–90,5	–91,5	–91,5	–80	–48,1
22	f	80	126	138	250	400	600	850	1104	1350	1594	2033	2208	2248	N/A
	P	–72,5	–48,9	–48,9	–53,3	–58,3	–63,5	–68,8	–73,6	–83,2	–91,5	–91,5	–80	–48,1	N/A

IL		f_1 P_1	f_2 P_2	f_3 P_3	f_4 P_4	f_5 P_5	f_6 P_6	f_7 P_7	f_8 P_8	f_9 P_9	f_{10} P_{10}	f_{11} P_{11}	f_{12} P_{12}	f_{13} P_{13}	f_{14} P_{14}
23	f	80	125	138	250	400	600	850	1104	1350	1540	2033	2208	2248	N/A
	P	–72,5	–49,3	–49,3	–54	–59,2	–64,5	–70,1	–75,1	–84,8	–91,5	–91,5	–80	–48,1	N/A
24	f	80	124	138	250	400	600	850	1104	1350	1491	2031	2206	2246	N/A
	P	–72,5	–49,8	–49,8	–54,6	–60	–65,5	–71,3	–76,5	–86,3	–91,5	–91,5	–80	–48,1	N/A
25	f	80	123	138	250	400	600	850	1104	1350	1447	1911	2086	2126	2208
	P	–72,5	–50,3	–50,3	–55,2	–60,8	–66,5	–72,5	–77,8	–87,8	–91,5	–91,5	–80	–47,8	–48
26	f	80	122	138	250	400	600	850	1104	1350	1406	1807	1982	2022	2208
	P	–72,5	–50,7	–50,7	–55,8	–61,6	–67,5	–73,6	–79,2	–89,3	–91,5	–91,5	–80	–47,6	–48
27	f	80	121	138	250	400	600	850	1104	1369	1693	1868	1908	2208	N/A
	P	–72,5	–51,1	–51,1	–56,4	–62,3	–68,4	–74,7	–80,4	–91,5	–91,5	–80	–47,3	–48	N/A
28	f	80	120	138	250	400	600	850	1104	1334	1593	1768	1808	2208	N/A
	P	–72,5	–51,5	–51,5	–57	–63,1	–69,3	–75,8	–81,7	–91,5	–91,5	–80	–47	–48	N/A
29	f	80	119	138	250	400	600	850	1104	1301	1505	1680	1720	2208	N/A
	P	–72,5	–51,9	–51,9	–57,5	–63,8	–70,2	–76,8	–82,9	–91,5	–91,5	–80	–46,8	–48	N/A
30	f	80	118	138	250	400	600	850	1104	1270	1433	1608	1648	2208	N/A
	P	–72,5	–52,3	–52,3	–58,1	–64,5	–71	–77,9	–84	–91,5	–91,5	–80	–46,6	–48	N/A
31	f	80	117	138	250	400	600	850	1104	1240	1380	1555	1595	1622	2208
	P	–72,5	–52,8	–52,7	–58,6	–65,2	–71,9	–78,9	–85,2	–91,5	–91,5	–80	–46,1	–46,5	–48
32	f	80	116	138	250	400	600	850	1104	1205	1322	1497	1538	1622	2208
	P	–72,5	–53,2	–53,2	–59,3	–66	–73	–80,2	–86,7	–91,5	–91,5	–80	–45,1	–46,5	–48
33	f	80	115	138	250	400	600	850	1104	1172	1268	1443	1485	1622	2208
	P	–72,5	–53,7	–53,7	–59,9	–66,9	–74	–81,5	–88,2	–91,5	–91,5	–80	–44,2	–46,5	–48
34	f	80	114	138	250	400	600	850	1104	1141	1217	1392	1434	1622	2208
	P	–72,5	–54,2	–54,2	–60,6	–67,8	–75,1	–82,7	–89,6	–91,5	–91,5	–80	–43,6	–46,5	–48
35	f	80	113	138	250	400	600	850	1104	1111	1169	1344	1387	1622	2208
	P	–72,5	–54,7	–54,7	–61,3	–68,6	–76,2	–84	–91,1	–91,5	–91,5	–80	–42,4	–46,5	–48
36	f	80	112	138	250	400	600	850	1061	1122	1297	1341	1622	2208	N/A
	P	–72,5	–55,2	–55,2	–61,9	–69,5	–77,2	–85,3	–91,5	–91,5	–80	–41,6	–46,5	–48	N/A
37	f	80	111	138	250	400	600	850	1009	1077	1252	1296	1622	2208	N/A
	P	–72,5	–55,7	–55,7	–62,6	–70,4	–78,3	–86,6	–91,5	–91,5	–80	–41	–46,5	–48	N/A
38	f	80	110	138	250	400	600	850	962	1036	1211	1256	1622	2208	N/A
	P	–72,5	–56,2	–56,2	–63,3	–71,2	–79,4	–87,9	–91,5	–91,5	–80	–39,9	–46,5	–48	N/A
39	f	80	109	138	250	400	600	850	919	996	1171	1217	1622	2208	N/A
	P	–72,5	–56,6	–56,6	–63,9	–72,1	–80,5	–89,2	–91,5	–91,5	–80	–39	–46,5	–48	N/A
40	f	80	108	138	250	400	600	850	880	959	1134	1180	1622	2208	N/A
	P	–72,5	–57,1	–57,1	–64,6	–73	–81,5	–90,4	–91,5	–91,5	–80	–38,3	–46,5	–48	N/A
41	f	80	107	138	250	400	600	843	921	1096	1143	1622	2208	N/A	N/A
	P	–72,5	–57,6	–57,6	–65,3	–73,8	–82,6	–91,5	–91,5	–80	–37,4	–46,5	–48	N/A	N/A
42	f	80	106	138	250	400	600	803	857	1032	1079	1104	1622	2208	N/A
	P	–72,5	–58,1	–58,1	–66	–74,7	–83,7	–91,5	–91,5	–80	–36,5	–36,5	–46,5	–48	N/A
43	f	80	105	138	250	400	600	768	800	975	1021	1104	1622	2208	N/A
	P	–72,5	–58,6	–58,6	–66,6	–75,6	–84,8	–91,5	–91,5	–80	–36,7	–36,5	–46,5	–48	N/A
44	f	80	104	138	250	400	600	735	749	924	970	1104	1622	2208	N/A
	P	–72,5	–59,1	–59,1	–67,3	–76,4	–85,8	–91,5	–91,5	–80	–36,5	–36,5	–46,5	–48	N/A
45	f	80	103	138	250	400	600	703	877	922	1104	1622	2208	N/A	N/A
	P	–72,5	–59,6	–59,6	–68	–77,3	–86,9	–91,4	–80	–36,5	–36,5	–46,5	–48	N/A	N/A
>45	f	80	103	138	250	400	600	703	877	922	1104	1622	2208	N/A	N/A
	P	–91,5	–91,5	–91,5	–91,5	–91,5	–91,5	–91,4	–80	–36,5	–36,5	–46,5	–48	N/A	N/A

NOTE 1: The label "N/A" denotes that a breakpoint is not used. The equivalent physical cable length L of the cable (last column of the table) is for information only, and estimated from a 0.5 mm GPLK cable model (model "KPN_L1", also known as "TP 150" in [2]).

NOTE 2: The breakpoints for IL > 45 dB may be too restrictive for VDSL2, refinements are for further study.

In the special case that VDSL2 is deployed from the local exchange, the attenuation length is zero (IL=0), and the associated rows from the table apply. Figure 1 illustrates the limits of the spectral powers (measured in 10 kHz and in 100 kHz) as function of the frequency, according to the specifications in table 2 and 3.

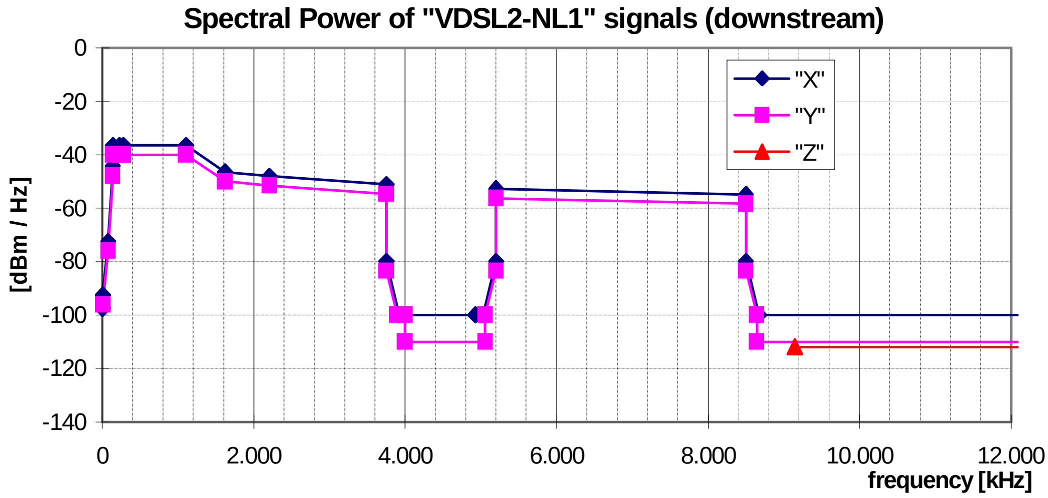

Figure 1: Spectral Power for “VDSL2-NL1” downstream signals, as specified in table 2 and 3 for IL=0 dB.

When VDSL2 is deployed from the cabinet, shaping of the above spectral powers can be significant between 134 kHz and 2500 kHz. Figure 2 illustrates the limits of these spectral powers (measured in 10 kHz and in 100 kHz) for various attenuation distances (for IL =10 dB, IL=20 dB and IL=40 dB).

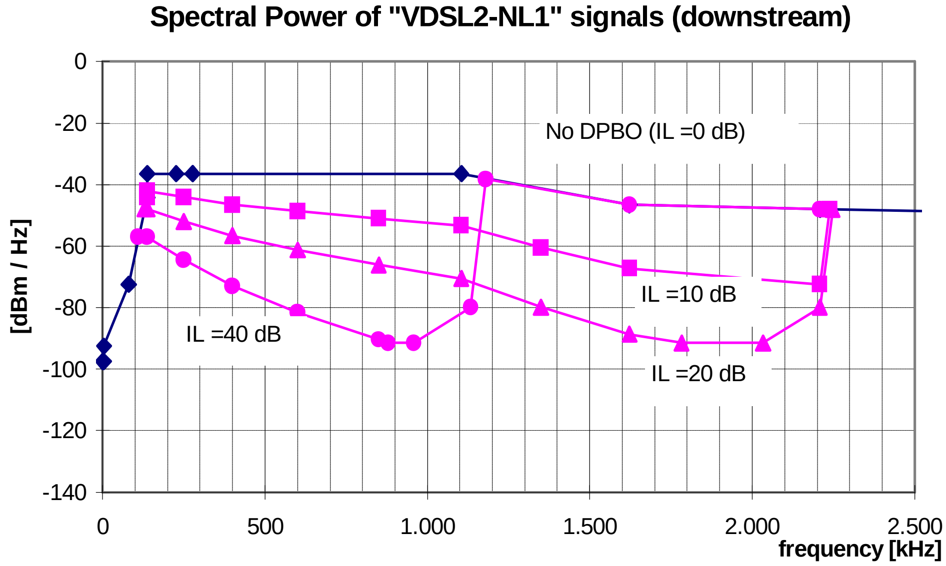

Figure 2: Spectral Power for “VDSL2-NL1” downstream signals, as specified in table 2 and 3, for a frequency band where downstream PSD Shaping has been applied.

2.1.5. 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 maximum 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.
The way this information is to be acquired and handled is no part of the signal description. All methods enabling compliance with both transmit and receive limits are therefore considered as adequate. The ITU-T recommendation G993.2 [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 4, 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 5.
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 4 and 5 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 3 and 4 illustrate these NBSP limits in a bandwidth-normalized way.

NOTE 1: The NBSP specification in table 4 is reconstructed from the commonly used PSD specifications in [1] (similar to figure 4), and used here since the NBSP approach 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 4) 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 5) 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.

Table 4: Break points of the NBSP limits, of the upstream transmit signal.

Centre frequency f	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
0,1 kHz	600 Ω	–77,5 dBm	100 Hz	–97,5 dBm/Hz	“X”
4 kHz	600 Ω	–77,5 dBm	100 Hz	–97,5 dBm/Hz	
4 kHz	100 Ω	–52,5 dBm	10 kHz	–92,5 dBm/Hz	
25,875 kHz	100 Ω	+5,5 dBm	10 kHz	–34,5 dBm/Hz	
50 kHz	100 Ω	+5,5 dBm	10 kHz	–34,5 dBm/Hz	
80 kHz	100 Ω	+5,5 dBm	10 kHz	–34,5 dBm/Hz	
120 kHz	100 Ω	+5,5 dBm	10 kHz	–34,5 dBm/Hz	
138 kHz	100 Ω	+5,5 dBm	10 kHz	–34,5 dBm/Hz	
243 kHz	100 Ω	–53,2 dBm	10 kHz	–93,2 dBm/Hz	
686 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
783 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
2825 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
3000 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	

Centre frequency f	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
3000 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
3575 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
3750 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
3750 kHz	100 Ω	–11,2 dBm	10 kHz	–51,2 dBm/Hz	
5200 kHz	100 Ω	–12,7 dBm	10 kHz	–52,7 dBm/Hz	
5200 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
5375 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
6875 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
7050 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
7050 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
8325 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
8500 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
8500 kHz	100 Ω	–14,8 dBm	10 kHz	–54,8 dBm/Hz	
10000 kHz	100 Ω	–15,5 dBm	10 kHz	–55,5 dBm/Hz	
12000 kHz	100 Ω	–15,5 dBm	10 kHz	–55,5 dBm/Hz	
12000 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
12175 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
14350 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
14351 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
14526 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
30000 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
50 kHz	100 Ω	+12 dBm	100 kHz	–38 dBm/Hz	“Y”
80 kHz	100 Ω	+12 dBm	100 kHz	–38 dBm/Hz	
120 kHz	100 Ω	+12 dBm	100 kHz	–38 dBm/Hz	
138 kHz	100 Ω	+12 dBm	100 kHz	–38 dBm/Hz	
243 kHz	100 Ω	–46,7 dBm	100 kHz	–96,7 dBm/Hz	
686 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
783 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
2825 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
2999,999 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
3000 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
3575 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
3749,999 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
3750 kHz	100 Ω	–5,7 dBm	100 kHz	–54,7 dBm/Hz	
5199,999 kHz	100 Ω	–6,2 dBm	100 kHz	–56,2 dBm/Hz	
5200 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
5375 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
6875 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
7049,999 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
7050 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
8325 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
8499,999 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
8500 kHz	100 Ω	–8,3 dBm	100 kHz	–58,3 dBm/Hz	
10000 kHz	100 Ω	–9 dBm	100 kHz	–59 dBm/Hz	
11999,999 kHz	100 Ω	–9 dBm	100 kHz	–59 dBm/Hz	
12000 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
12175 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
14350 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
14351 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
14526 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
30000 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
12675 kHz	100 Ω	–52 dBm	1 MHz	–112 dBm/Hz	“Z”
14350 kHz	100 Ω	–52 dBm	1 MHz	–112 dBm/Hz	
14351 kHz	100 Ω	–52 dBm	1 MHz	–112 dBm/Hz	
14526 kHz	100 Ω	–52 dBm	1 MHz	–112 dBm/Hz	
30000 kHz	100 Ω	–52 dBm	1 MHz	–112 dBm/Hz	

Centre frequency f	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
NOTE 1: The PSD values between breakpoints shall be obtained by interpolation between adjacent breakpoints as follows: • below *3575* kHz: on a dB / $\log_{10}(f)$ basis and • above *3575* kHz: on a dB / *f* basis					

Table 5: Break points of the NBSP 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	

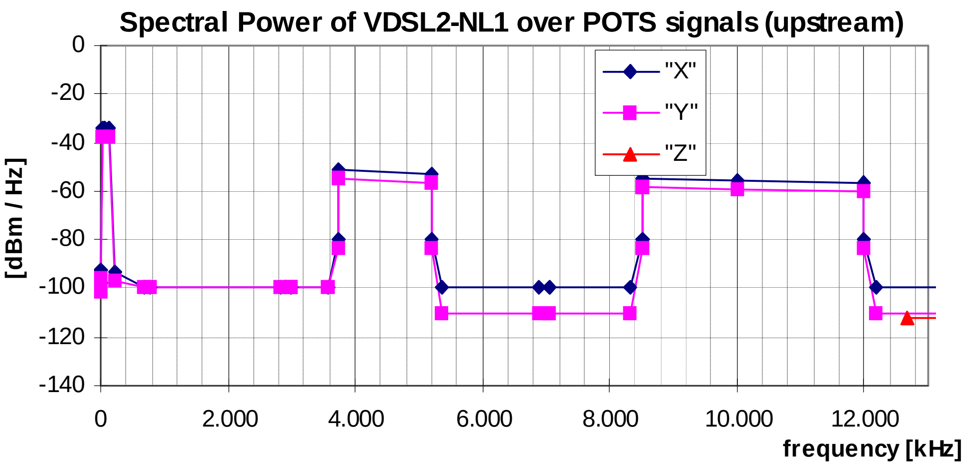

Figure 3: Spectral Power for "VDSL2-NL1" upstream *transmit* signals, as specified in table 4.

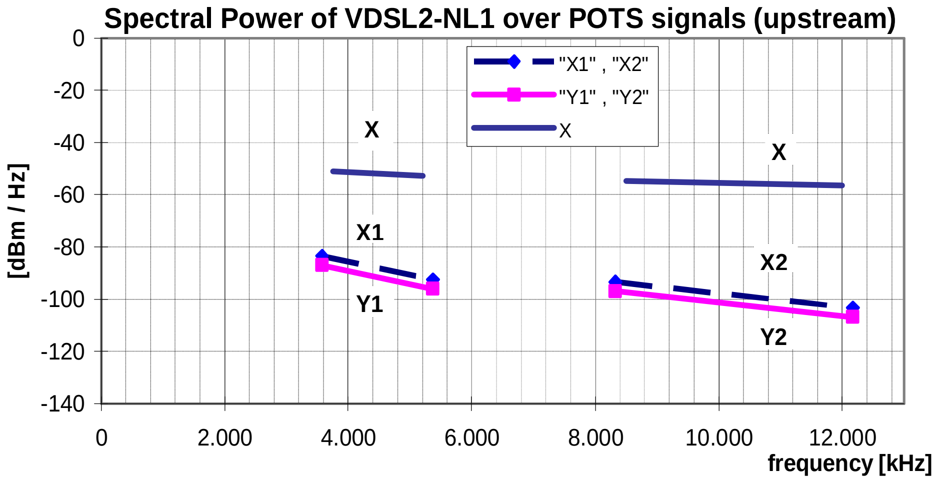

Figure 4: Spectral Power for "VDSL2-NL1" upstream *receive* signals, as specified in table 5.

2.1.6. Unbalance about earth (upstream and downstream)

To be compliant with this signal category, the balance of the signal that may flow through the LT-port or NT-port shall exceed minimum requirements, under the condition that the local loop wiring and its termination is well balanced. This can be verified by a Longitudinal Output Voltage (LOV) and a Longitudinal Conversion Loss (LCL) measurement at the source of that signal, as specified in clause 13.3.2 and 13.3.3. The minimum LOV and LCL requirements hold for what can be observed at the ports of the Local Loop Wiring, when the Local Loop Wiring is replaced by an artificial impedance network described in clause 13.3.2 and 13.3.3.

The differential termination impedance for LOV and LCL measurements shall be chosen equally to the design impedance R_T = 100 Ω of the Signal Source under test.

The observed LOV shall have an rms voltage of below the value specified in table 6, measured in a *power* bandwidth B, centred over any frequency in the range from f_{min} to f_{max}, and averaged in any one second period. Compliance with this limitation is required with a longitudinal terminating impedance having value $Z_L(\omega) = R_L + 1 / (j\omega \times C_L)$ for all frequencies between f_{min} to f_{max}. Clause 13.3.2 defines an example measurement method for longitudinal output voltage.

The observed LCL shall be higher than the lower limits given in figure 5. The LCL values of the associated break frequencies of this figure are given in table 7. Clause 13.3.3 defines an example measurement method for longitudinal conversion loss. To be compliant with this signal category, this requirement shall be met for both the switched-on and switched-off mode of the signal source.

Reference: TS 101 270-1, clauses 8.3.3 and E.3.2 [2].

Table 6: Values for the LOV limits

	LOV	B	f_{min}	f_{max}	R_L	C_L
downstream	–46 dBV	10 kHz	5,1 kHz	1 825 kHz	100 Ω	150 nF
upstream	–46 dBV	10 kHz	5,1 kHz	210 kHz	100 Ω	150 nF

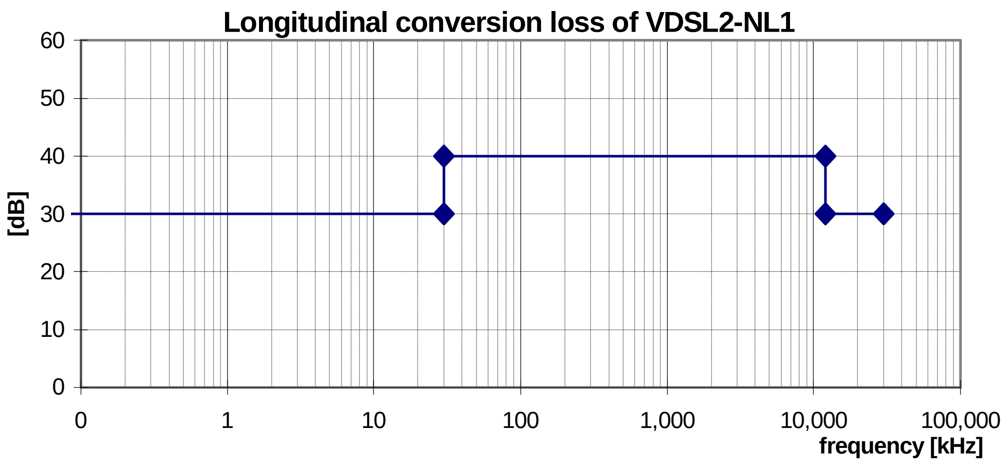

Figure 5: Minimum longitudinal conversion loss

Table 7: Frequencies and LCL values of the breakpoints of the LCL mask in figure 5.

Frequency	LCL
< 30 kHz	30 dB
30 kHz	40 dB
12 MHz	40 dB
12 MHz	30 dB
30 MHz	30 dB

2.2. "VDSL2-NL2” signals (over ISDN)

This category covers signals up to 12 MHz, generated by VDSL2 transmission equipment using band plan 998 (limit PSD mask B8-6). These signals may share the same wire pair with ISDN signals.

This signal description is derived from the ITU VDSL2 recommendation [1] and accounts for Power Back-Off in both downstream (DPBO, also kown as PSD shaping) and upstream (UPBO) direction.

- The downstream signal limits are dependent on the *attenuation distance* between the local exchange and cabinet (“primary cable”), defined as the insertion loss (IL) of that loop measured at 300 kHz into a resistive load of 100 Ω. These limits are specified for a discrete number of (integer) attenuation distances. For all other attenuation distances, the downstream limits for the nearest specified IL-values apply, and not by means of interpolating the limits.
- The upstream signal limits are fixed, but defined in such a way that the actual transmit levels changes with the insertion loss between cabinet and customer premises.

A signal can be classified as a “VDSL2-NL2” signal if it is compliant with all clauses below.

2.2.1. Total signal power (downstream only)

To be compliant with this signal category, the mean downstream signal power into a resistive load of 100 Ω shall not exceed the levels given in table 8, measured within a frequency band from at least 4 kHz to 30 MHz. In the special case of VDSL2 deployment from the local exchange, the limits associated with IL=0 apply.

Table 8: Total downstream transmit power as function of the measured insertion loss of the loop between local exchange and cabinet.

IL [dB @ 300 kHz]	Downstream Total signal power [dBm]	L [m]
0	20,8	0
1	19,5	101
2	18,4	202
3	17,4	303
4	16,4	404
5	15,5	506
6	14,8	607
7	14,1	708
8	13,6	809
9	13,1	910
10	12,7	1011
11	12,4	1112
12	12,1	1213
13	11,9	1315
14	11,8	1416
15	11,7	1517
16	11,6	1618
17	11,5	1719
18	11,5	1820
19	11,4	1921
20	11,4	2022
21	11,4	2123
22	11,4	2225
23	11,3	2326
24	11,3	2427
25	11,6	2528
26	11,8	2629
27	12,1	2730
28	12,3	2831
29	12,5	2932
30	12,6	3034
31	12,8	3135
32	12,9	3236
33	13,1	3337
34	13,3	3438
35	13,5	3539
36	13,8	3640
37	14,0	3741
38	14,3	3842
39	14,7	3944
40	15,0	4045
41	15,4	4146
42	16,1	4247
43	16,6	4348
44	17,1	4449
45	17,5	4550
>45	17,5	>4550

NOTE 1: The IL-values are normative. The L-values are informative and represent estimated loop lengths for a commonly used Dutch cable.

NOTE 2: Current implementations of VDSL2 transmitters, compliant with G993.2 [1], are not expected to be capable of generating output powers of more then 20,5 dBm

NOTE 3: The power limit specified for IL>45 dB may be too restrictive for VDSL2; refinement is for further study.

2.2.2. Total signal power (upstream only)

To be compliant with this signal category, the mean upstream signal power into a resistive load of 100 Ω shall not exceed a level of +14,5 dBm, measured within a frequency band from at least 4 kHz to 30 MHz. Note that this limit is an upper limit only; the actual level may be significantly lower when the additional spectral receive limits to upstream signals require a strong power back-off in short loops.

Reference: ITU- T Recommendation G.993.2 [1], chapter 6.

2.2.3. Peak amplitude (upstream and downstream)

To be compliant with this signal category, the nominal voltage peak of the largest signal pulse into a resistive load of 100 Ω shall not exceed a level of 19V (38 V peak-peak), measured within a frequency band from at least 100 Hz to 30 MHz. The definition and measurement method of peak amplitude is specified in clause 13.1.

2.2.4. Narrow-band signal power (downstream only)

To be compliant with this signal category, the Narrow-Band Signal Power (NBSP) into a resistive load impedance ***R*** for a given IL-value, shall not exceed the limits given in table 9 and table 10, at any point in the frequency range 100 Hz to 30 MHz. These tables 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 2500 kHz and on a linear (Hz) - linear (dB) scale above 2500 kHz. Figure 6 and figure 7 illustrate the NBSP in a bandwidth-normalized way. The NBSP is the average power ***P*** of a sending signal into a load resistance ***R***, within a *power* bandwidth ***B***. The measurement method of the NBSP is described in clause 13.2.

NOTE 1: The NBSP specification in table 9 is reconstructed from the commonly used PSD specifications in [1] (similar to figure 6), 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 this signal category has been split into three overlapping limits: "X", “Y” and "Z". All these upper limits shall hold simultaneously. The 10 kHz bandwidth values represent the "maximum PSD values" [1], and includes the pass band ripple. The 100 kHz bandwidth values represent the "average PSD values" in the passband 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 (see [4, 3]).

Reference: ITU-T Recommendation G.993.2 [1], clause B.2.5.

The description of this signal characteristic is derived from VDSL2 “band plan 998” signals with PSD mask “B8-6”. Downstream PSD Shaping has been applied between 101.2 KHz and 2500 kHz.

Table 9: Break points of the NBSP limits, of the downstream transmit signal

Centre frequency f	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
0,1 kHz	600 Ω	–77,5 dBm	100 Hz	–97,5 dBm/Hz	"X"
4 kHz	600 Ω	–77,5 dBm	100 Hz	–97,5 dBm/Hz	
4 kHz	100 Ω	–52,5 dBm	10 kHz	–92,5 dBm/Hz	
80 kHz	100 Ω	–52,5 dBm	10 kHz	–92,5 dBm/Hz	
f_1	100 Ω	P_1 + 40 dB	10 kHz	P_1	
f_2	100 Ω	P_2 + 40 dB	10 kHz	P_2	
f_3	100 Ω	P_3 + 40 dB	10 kHz	P_3	
f_4	100 Ω	P_4 + 40 dB	10 kHz	P_4	
f_5	100 Ω	P_5 + 40 dB	10 kHz	P_5	
f_6	100 Ω	P_6 + 40 dB	10 kHz	P_6	
f_7	100 Ω	P_7 + 40 dB	10 kHz	P_7	
f_8	100 Ω	P_8 + 40 dB	10 kHz	P_8	
f_9	100 Ω	P_9 + 40 dB	10 kHz	P_9	
f_{10}	100 Ω	P_{10} + 40 dB	10 kHz	P_{10}	
f_{11}	100 Ω	P_{11} + 40 dB	10 kHz	P_{11}	
f_{12}	100 Ω	P_{12} + 40 dB	10 kHz	P_{12}	
f_{13}	100 Ω	P_{13} + 40 dB	10 kHz	P_{13}	
f_{14}	100 Ω	P_{14} + 40 dB	10 kHz	P_{14}	
2500 kHz	100 Ω	–8,8 dBm	10 kHz	–48,8 dBm/Hz	
3749,999 kHz	100 Ω	–11,2 dBm	10 kHz	–51,2 dBm/Hz	
3750 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
3925 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
4925 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
5025 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
5199,999 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
5200 kHz	100 Ω	–12,7 dBm	10 kHz	–52,7 dBm/Hz	
8499,999 kHz	100 Ω	–14,8 dBm	10 kHz	–54,8 dBm/Hz	
8500 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
8675 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
30000 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
50 kHz	100 Ω	–46 dBm	100 kHz	–96 dBm/Hz	"Y"
80 kHz	100 Ω	–46 dBm	100 kHz	–96 dBm/Hz	
f_1	100 Ω	P_1 + 46,5 dB	100 kHz	P_1 –3,5 dB	
f_2	100 Ω	P_2 + 46,5 dB	100 kHz	P_2 –3,5 dB	
f_3	100 Ω	P_3 + 46,5 dB	100 kHz	P_3 –3,5 dB	
f_4	100 Ω	P_4 + 46,5 dB	100 kHz	P_4 –3,5 dB	
f_5	100 Ω	P_5 + 46,5 dB	100 kHz	P_5 –3,5 dB	
f_6	100 Ω	P_6 + 46,5 dB	100 kHz	P_6 –3,5 dB	
f_7	100 Ω	P_7 + 46,5 dB	100 kHz	P_7 –3,5 dB	
f_8	100 Ω	P_8 + 46,5 dB	100 kHz	P_8 –3,5 dB	
f_9	100 Ω	P_9 + 46,5 dB	100 kHz	P_9 –3,5 dB	
f_{10}	100 Ω	P_{10} + 46,5 dB	100 kHz	P_{10} –3,5 dB	
f_{11}	100 Ω	P_{11} + 46,5 dB	100 kHz	P_{11} –3,5 dB	
f_{12}	100 Ω	P_{12} + 46,5 dB	100 kHz	P_{12} –3,5 dB	
f_{13}	100 Ω	P_{13} + 46,5 dB	100 kHz	P_{13} –3,5 dB	
f_{14}	100 Ω	P_{14} + 46,5 dB	100 kHz	P_{14} –3,5 dB	
2500 kHz	100 Ω	–2,3 dBm	100 kHz	–52,3 dBm/Hz	
3749,999 kHz	100 Ω	–4,5 dBm	100 kHz	–54,7 dBm/Hz	
3750 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
3894 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
3999,999 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
4000 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
5055 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
5056 kHz	100 Ω	–62 dBm	100 kHz	–99,9 dBm/Hz	
5199,999 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
5200 kHz	100 Ω	–6,2 dBm	100 kHz	–56,2 dBm/Hz	
8499,999 kHz	100 Ω	–8,3 dBm	100 kHz	–58,3 dBm/Hz	

Centre frequency f	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
8500 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
8644 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
8645 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
30000 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
9145 kHz	100 Ω	–52 dBm	1 MHz	–112 dBm/Hz	“Z”
30000 kHz	100 Ω	–52 dBm	1 MHz	–112 dBm/Hz	
Note 1: The limits between breakpoints shall be obtained by interpolation between adjacent breakpoints on a dB / log(f) basis below 2500 kHz and on a dB/f basis above 2500 kHz Note 2: The limits “Y” between 50 kHz and 2500 kHz are 3,5 dB lower then the associated limits “X”. This may be a bit too restrictive for VDSL2 when the PSD slope in this shaping region becomes steep. Refinements for the limits at these breakpoints require further study.					

Table 10: Definition of parameter f_k and P_k, (with k = 1 to 14), of the downstream NBSP limits in table 9.

IL		f_1 P_1	f_2 P_2	f_3 P_3	f_4 P_4	f_5 P_5	f_6 P_6	f_7 P_7	f_8 P_8	f_9 P_9	f_{10} P_{10}	f_{11} P_{11}	f_{12} P_{12}	f_{13} P_{13}	f_{14} P_{14}
0	f	101.2	227.11	275.999	276	1104	1622	2208	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	P	–92.5	–62	–48.5	–36.5	–36.5	–46.5	–48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1	f	101.2	227.11	275.999	276	850	1104	1622	2208	2211	N/A	N/A	N/A	N/A	N/A
	P	–92.5	–62	–48.5	–37.3	–38	–38.2	–48.6	–50.3	–48	N/A	N/A	N/A	N/A	N/A
2	f	101.2	227.11	275.999	276	600	1104	1622	2208	2214	N/A	N/A	N/A	N/A	N/A
	P	–92.5	–62	–48.5	–38.1	–38.9	–39.8	–50.6	–52.7	–48	N/A	N/A	N/A	N/A	N/A
3	f	101.2	227.11	275.999	276	600	850	1104	1622	2208	2217	N/A	N/A	N/A	N/A
	P	–92.5	–62	–48.5	–38.9	–40.1	–40.9	–41.5	–52.7	–55.2	–48	N/A	N/A	N/A	N/A
4	f	101.2	227.11	275.999	276	400	600	850	1104	1622	2208	2220	N/A	N/A	N/A
	P	–92.5	–62	–48.5	–39.7	–40.4	–41.4	–42.3	–43.2	–54.8	–57.6	–48	N/A	N/A	N/A
5	f	101.2	227.11	275.999	276	400	600	850	1104	1350	1622	2208	2223	N/A	N/A
	P	–92.5	–62	–48.5	–40.5	–41.4	–42.6	–43.8	–44.9	–51.1	–56.8	–60.1	–48.1	N/A	N/A
6	f	101.2	227.11	275.999	276	400	600	850	1104	1350	1622	2208	2226	2500	N/A
	P	–92.5	–62	–48.5	–41.3	–42.4	–43.8	–45.2	–46.5	–52.9	–58.9	–62.5	–48.1	–48.8	N/A
7	f	101.2	227.11	275.999	276	400	600	850	1104	1350	1622	2208	2229	2500	N/A
	P	–92.5	–62	–48.5	–42.1	–43.4	–45	–46.7	–48.2	–54.8	–61	–65	–48.2	–48.8	N/A
8	f	101.2	227.11	275.999	276	400	600	850	1104	1350	1622	2208	2232	2500	N/A
	P	–92.5	–62	–48.5	–42.9	–44.4	–46.2	–48.1	–49.9	–56.7	–63	–67.5	–48.3	–48.8	N/A
9	f	101.2	227.11	275.999	276	400	600	850	1104	1350	1622	2208	2235	2500	N/A
	P	–92.5	–62	–48.5	–43.7	–45.4	–47.4	–49.6	–51.6	–58.5	–65.1	–69.9	–48.3	–48.8	N/A
10	f	101.2	227.11	275.999	276	400	600	850	1104	1350	1622	2208	2239	N/A	N/A
	P	–92.5	–62	–48.5	–44.6	–46.4	–48.7	–51.1	–53.3	–60.5	–67.3	–72.5	–48.1	N/A	N/A
11	f	101.2	227.11	275.999	276	400	600	850	1104	1350	1622	2208	2242	2500	N/A
	P	–92.5	–62	–48.5	–45.5	–47.5	–50.1	–52.8	–55.2	–62.6	–69.6	–75.3	–48.2	–48.8	N/A
12	f	101.2	227.11	275.999	276	400	600	850	1104	1350	1622	2208	2246	N/A	N/A
	P	–92.5	–62	–48.5	–46.4	–48.6	–51.5	–54.4	–57.1	–64.7	–71.9	–78.1	–48.1	N/A	N/A
13	f	101.2	227.11	275.999	276	400	600	850	1104	1350	1622	2198	2208	2248	N/A
	P	–92.5	–62	–48.5	–47.3	–49.7	–52.8	–56	–58.9	–66.8	–74.2	–80.6	–80	–48.1	N/A
14	f	101.2	227.11	275.999	276	400	600	850	1104	1350	1622	2162	2208	2248	N/A
	P	–92.5	–62	–48.5	–48.1	–50.7	–54.1	–57.6	–60.7	–68.8	–76.4	–82.9	–80	–48.1	N/A
15	f	101.2	227.11	274	276	400	600	850	1104	1350	1622	2129	2208	2248	N/A
	P	–92.5	–62	–49	–49	–51.8	–55.4	–59.1	–62.5	–70.7	–78.6	–85.1	–80	–48.1	N/A
16	f	101.2	227.11	271	276	400	600	850	1104	1350	1622	2097	2208	2248	N/A
	P	–92.5	–62	–49.8	–49.8	–52.8	–56.6	–60.6	–64.2	–72.6	–80.7	–87.2	–80	–48.1	N/A
17	f	101.2	227.11	268	276	400	600	850	1104	1350	1622	2067	2208	2248	N/A
	P	–92.5	–62	–50.6	–50.6	–53.8	–57.8	–62	–65.9	–74.5	–82.8	–89.2	–80	–48.1	N/A
18	f	101.2	227.11	265	276	400	600	850	1104	1350	1622	2039	2208	2248	N/A
	P	–92.5	–62	–51.4	–51.4	–54.7	–59	–63.5	–67.5	–76.3	–84.8	–91.1	–80	–48.1	N/A
19	f	101.2	227.11	262	276	400	600	850	1104	1350	1622	1912	2033	2208	2248
	P	–92.5	–62	–52.1	–52.1	–55.7	–60.2	–64.9	–69.1	–78.1	–86.7	–91.5	–91.5	–80	–48.1
20	f	101.2	227.11	259	276	400	600	850	1104	1350	1622	1782	2033	2208	2248
	P	–92.5	–62	–52.9	–52.9	–56.6	–61.3	–66.2	–70.6	–79.8	–88.7	–91.5	–91.5	–80	–48.1
21	f	101.2	227.11	256	276	400	600	850	1104	1350	1622	1673	2033	2208	2248
	P	–92.5	–62	–53.7	–53.6	–57.5	–62.4	–67.5	–72.2	–81.5	–90.5	–91.5	–91.5	–80	–48.1
22	f	101.2	227.11	253.999	276	400	600	850	1104	1350	1594	2033	2208	2248	N/A
	P	–92.5	–62	–54.3	–54.3	–58.3	–63.5	–68.8	–73.6	–83.2	–91.5	–91.5	–80	–48.1	N/A
23	f	101.2	227.11	251	276	400	600	850	1104	1350	1540	2033	2208	2248	N/A
	P	–92.5	–62	–55.1	–55	–59.2	–64.5	–70.1	–75.1	–84.8	–91.5	–91.5	–80	–48.1	N/A

IL		f_1 P_1	f_2 P_2	f_3 P_3	f_4 P_4	f_5 P_5	f_6 P_6	f_7 P_7	f_8 P_8	f_9 P_9	f_{10} P_{10}	f_{11} P_{11}	f_{12} P_{12}	f_{13} P_{13}	f_{14} P_{14}
24	f	101.2	227.11	249	276	400	600	850	1104	1350	1491	2031	2206	2246	N/A
	P	–92.5	–62	–55.7	–55.7	–60	–65.5	–71.3	–76.5	–86.3	–91.5	–91.5	–80	–48.1	N/A
25	f	101.2	227.11	247	276	400	600	850	1104	1350	1447	1911	2086	2126	N/A
	P	–92.5	–62	–56.3	–56.3	–60.8	–66.5	–72.5	–77.8	–87.8	–91.5	–91.5	–80	–47.8	N/A
26	f	101.2	227.11	244	276	400	600	850	1104	1350	1406	1807	1982	2022	2208
	P	–92.5	–62	–57	–57	–61.6	–67.5	–73.6	–79.2	–89.3	–91.5	–91.5	–80	–47.6	–48
27	f	101.2	227.11	242	276	400	600	850	1104	1369	1693	1868	1908	2208	N/A
	P	–92.5	–62	–57.6	–57.6	–62.3	–68.4	–74.7	–80.4	–91.5	–91.5	–80	–47.3	–48	N/A
28	f	101.2	227.11	240	276	400	600	850	1104	1334	1593	1768	1808	2208	N/A
	P	–92.5	–62	–58.2	–58.2	–63.1	–69.3	–75.8	–81.7	–91.5	–91.5	–80	–47	–48	N/A
29	f	101.2	227.11	238	276	400	600	850	1104	1301	1505	1680	1720	2208	N/A
	P	–92.5	–62	–58.8	–58.7	–63.8	–70.2	–76.8	–82.9	–91.5	–91.5	–80	–46.8	–48	N/A
30	f	101.2	227.11	236	276	400	600	850	1104	1270	1433	1608	1648	2208	N/A
	P	–92.5	–62	–59.3	–59.3	–64.5	–71	–77.9	–84	–91.5	–91.5	–80	–46.6	–48	N/A
31	f	101.2	227.11	234	276	400	600	850	1104	1240	1380	1555	1595	1622	2208
	P	–92.5	–62	–59.9	–59.9	–65.2	–71.9	–78.9	–85.2	–91.5	–91.5	–80	–46.1	–46.5	–48
32	f	101.2	227.11	232	276	400	600	850	1104	1205	1322	1497	1538	1622	2208
	P	–92.5	–62	–60.6	–60.6	–66	–73	–80.2	–86.7	–91.5	–91.5	–80	–45.1	–46.5	–48
33	f	101.2	227.11	230	276	400	600	850	1104	1172	1268	1443	1485	1622	2208
	P	–92.5	–62	–61.3	–61.3	–66.9	–74	–81.5	–88.2	–91.5	–91.5	–80	–44.2	–46.5	–48
34	f	101.2	227.11	276	400	600	850	1104	1141	1217	1392	1434	1622	2208	N/A
	P	–92.5	–62	–62	–67.8	–75.1	–82.7	–89.6	–91.5	–91.5	–80	–43.6	–46.5	–48	N/A
35	f	101.2	223	276	400	600	850	1104	1111	1169	1344	1387	1622	2208	N/A
	P	–92.5	–62.7	–62.7	–68.6	–76.2	–84	–91.1	–91.5	–91.5	–80	–42.4	–46.5	–48	N/A
36	f	101.2	219	276	400	600	850	1061	1122	1297	1341	1622	2208	N/A	N/A
	P	–92.5	–63.4	–63.4	–69.5	–77.2	–85.3	–91.5	–91.5	–80	–41.6	–46.5	–48	N/A	N/A
37	f	101.2	215	276	400	600	850	1009	1077	1252	1296	1622	2208	N/A	N/A
	P	–92.5	–64.1	–64.1	–70.4	–78.3	–86.6	–91.5	–91.5	–80	–41	–46.5	–48	N/A	N/A
38	f	101.2	211	276	400	600	850	962	1036	1211	1256	1622	2208	N/A	N/A
	P	–92.5	–64.8	–64.8	–71.2	–79.4	–87.9	–91.5	–91.5	–80	–39.9	–46.5	–48	N/A	N/A
39	f	101.2	207	276	400	600	850	919	996	1171	1217	1622	2208	N/A	N/A
	P	–92.5	–65.5	–65.5	–72.1	–80.5	–89.2	–91.5	–91.5	–80	–39	–46.5	–48	N/A	N/A
40	f	101.2	203	276	400	600	850	880	959	1134	1180	1622	2208	N/A	N/A
	P	–92.5	–66.2	–66.2	–73	–81.5	–90.4	–91.5	–91.5	–80	–38.3	–46.5	–48	N/A	N/A
41	f	101.2	199	276	400	600	843	921	1096	1143	1622	2208	N/A	N/A	N/A
	P	–92.5	–67	–66.9	–73.8	–82.6	–91.5	–91.5	–80	–37.4	–46.5	–48	N/A	N/A	N/A
42	f	101.2	196	276	400	600	803	857	1032	1079	1104	1622	2208	N/A	N/A
	P	–92.5	–67.6	–67.6	–74.7	–83.7	–91.5	–91.5	–80	–36.5	–36.5	–46.5	–48	N/A	N/A
43	f	101.2	192	276	400	600	768	800	975	1021	1104	1622	2208	N/A	N/A
	P	–92.5	–68.4	–68.4	–75.6	–84.8	–91.5	–91.5	–80	–36.7	–36.5	–46.5	–48	N/A	N/A
44	f	101.2	188	276	400	600	735	749	924	970	1104	1622	2208	N/A	N/A
	P	–92.5	–69.1	–69.1	–76.4	–85.8	–91.5	–91.5	–80	–36.5	–36.5	–46.5	–48	N/A	N/A
45	f	101.2	185	276	400	600	703	877	922	1104	1622	2208	N/A	N/A	N/A
	P	–92.5	–69.8	–69.8	–77.3	–86.9	–91.4	–80	–36.5	–36.5	–46.5	–48	N/A	N/A	N/A
> 45	f	101.2	185	276	400	600	703	877	922	1104	1622	2208	N/A	N/A	N/A
	P	–92.5	–91.5	–91.5	–91.5	–91.5	–91.4	–80	–36.5	–36.5	–46.5	–48	N/A	N/A	N/A

NOTE 1: The label "N/A" denotes that a breakpoint is not used.
NOTE 2: The breakpoints for IL > 45 dB may be too restrictive for VDSL2, refinements are for further study.

In the special case that VDSL2 is deployed from the local exchange, the IL-value is zero. Figure 6 illustrates the limits of the spectral powers (measured in 10 kHz and in 100 kHz) as function of the frequency, according to the specifications in table 9 and table 10.

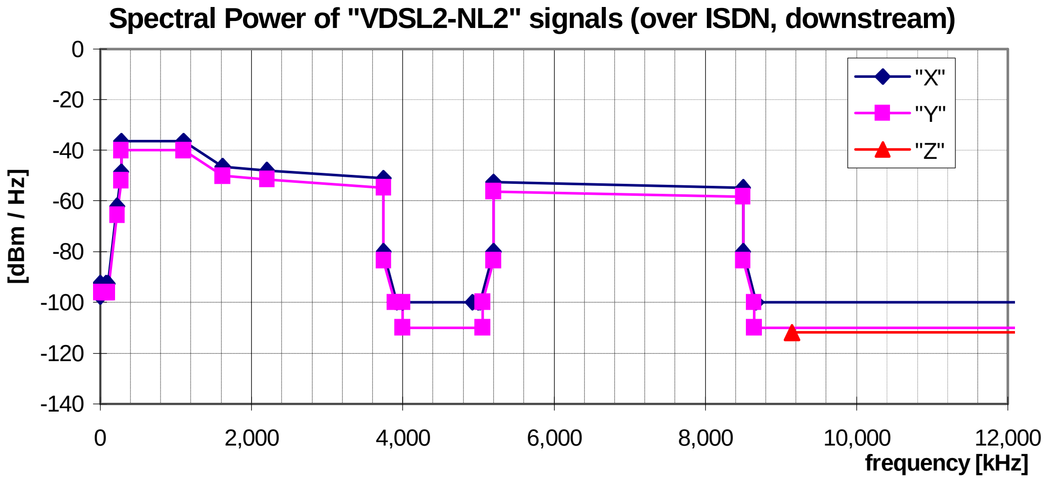

Figure 6: Spectral Power for “VDSL2-NL2” downstream signals (over ISDN), as specified in table 9 and table 10 for IL=0 dB.

When VDSL2 is deployed from the cabinet, shaping of the above spectral powers can be significant between 276 kHz and 2500 kHz. Figure 7 illustrates the limits of these spectral powers (measured in 10 kHz and in 100 kHz) for various IL-values (for IL =10 dB, IL=20 dB and IL=40 dB).

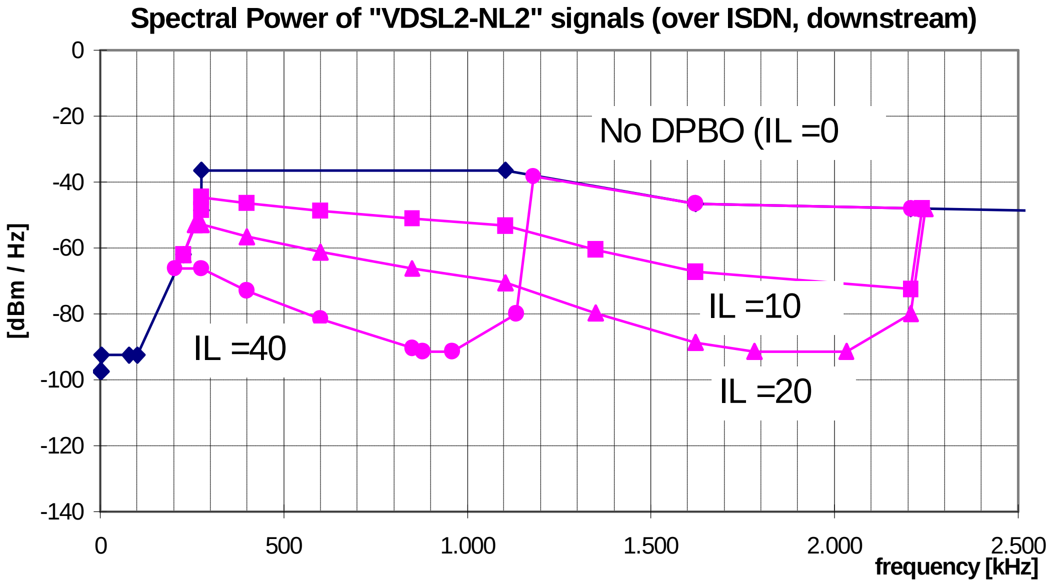

Figure 7: Spectral Power for “VDSL2-NL2” downstream signals (over ISDN), as specified in table 9 and 10 in the frequency region where downstream PSD Shaping has been applied.

2.2.5. 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 upstream limits for “VDSL2-NL2” signals are equal to the limits specified before for “VDSL2-NL1” signals, with the only difference that the transmit limits are different. The transmit limits for “VDSL2-NL2” signals are specified in table 11 and illustrated in figure 8.

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

Table 11: Break points of the NBSP limits, of the upstream transmit signal

Centre frequency f	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
0,1 kHz	600 Ω	–77,5 dBm	100 Hz	–97,5 dBm/Hz	“X”
4 kHz	600 Ω	–77,5 dBm	100 Hz	–97,5 dBm/Hz	
4 kHz	100 Ω	–52,5 dBm	10 kHz	–92,5 dBm/Hz	
50 kHz	100 Ω	–50 dBm	10 kHz	–90 dBm/Hz	
80 kHz	100 Ω	–41,8 dBm	10 kHz	–81,8 dBm/Hz	
120 kHz	100 Ω	5,5 dBm	10 kHz	–34,5 dBm/Hz	
276 kHz	100 Ω	5,5 dBm	10 kHz	–34,5 dBm/Hz	
508,8 kHz	100 Ω	–58 dBm	10 kHz	–98 dBm/Hz	
686 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
783 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
2825 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
3000 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
3000 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
3575 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
3750 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
3750 kHz	100 Ω	–11,2 dBm	10 kHz	–51,2 dBm/Hz	
5200 kHz	100 Ω	–12,7 dBm	10 kHz	–52,7 dBm/Hz	
5200 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
5375 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
6875 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
7050 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
7050 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
8325 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
8500 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
8500 kHz	100 Ω	–14,8 dBm	10 kHz	–54,8 dBm/Hz	
10000 kHz	100 Ω	–15,5 dBm	10 kHz	–55,5 dBm/Hz	
12000 kHz	100 Ω	–16,5 dBm	10 kHz	–56,5 dBm/Hz	
12000 kHz	100 Ω	–40 dBm	10 kHz	–80 dBm/Hz	
12175 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
14350 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
14351 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
14526 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
30000 kHz	100 Ω	–60 dBm	10 kHz	–100 dBm/Hz	
50 kHz	100 Ω	–43,5 dBm	100 kHz	–93.5 dBm/Hz	“Y”
80 kHz	100 Ω	–35,3 dBm	100 kHz	–85.3 dBm/Hz	
120 kHz	100 Ω	+12 dBm	100 kHz	–38 dBm/Hz	
276 kHz	100 Ω	+12 dBm	100 kHz	–38 dBm/Hz	
508,8 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
686 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
783 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
2825 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
2999,999 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
3000 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
3575 kHz	100 Ω	–50 dBm	100 kHz	–100 dBm/Hz	
3749,999 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
3750 kHz	100 Ω	–5,7 dBm	100 kHz	–54,7 dBm/Hz	
5199,999 kHz	100 Ω	–6,2 dBm	100 kHz	–56,2 dBm/Hz	
5200 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
5375 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
6875 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
7049,999 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
7050 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
8325 kHz	100 Ω	–60 dBm	100 kHz	–110 dBm/Hz	
8499,999 kHz	100 Ω	–33,5 dBm	100 kHz	–83,5 dBm/Hz	
8500 kHz	100 Ω	–8,3 dBm	100 kHz	–58,3 dBm/Hz	

Centre frequency f	Impedance R	Signal Level P	Power bandwidth B	Spectral Power P/B	
10000 kHz 11999,999 kHz 12000 kHz 12175 kHz 14350 kHz 14351 kHz 14526 kHz 30000 kHz	100 Ω 100 Ω 100 Ω 100 Ω 100 Ω 100 Ω 100 Ω 100 Ω	–9 dBm –10 dBm –33,5 dBm –60 dBm –60 dBm –60 dBm –60 dBm –60 dBm	100 kHz 100 kHz 100 kHz 100 kHz 100 kHz 100 kHz 100 kHz 100 kHz	–59 dBm/Hz –60 dBm/Hz –83,5 dBm/Hz –110 dBm/Hz –110 dBm/Hz –110 dBm/Hz –110 dBm/Hz –110 dBm/Hz	
12675 kHz 14350 kHz 14351 kHz 14526 kHz 30000 kHz	100 Ω 100 Ω 100 Ω 100 Ω 100 Ω	–52 dBm –52 dBm –52 dBm –52 dBm –52 dBm	1 MHz 1 MHz 1 MHz 1 MHz 1 MHz	–112 dBm/Hz –112 dBm/Hz –112 dBm/Hz –112 dBm/Hz –112 dBm/Hz	"Z"

NOTE 1: The PSD values between breakpoints shall be obtained by interpolation between adjacent breakpoints as follows:

- below *3575* kHz: on a dB / $\log_{10}(f)$ basis and
- above *3575* kHz: on a dB / *f* basis

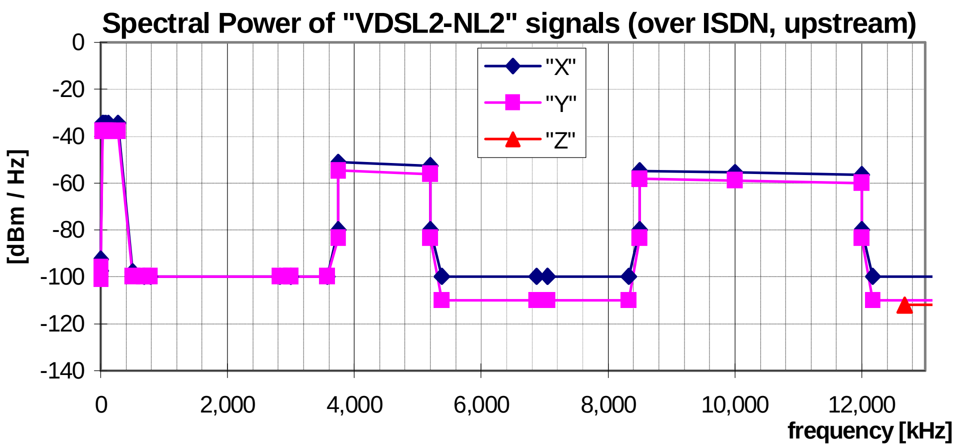

Figure 8: Spectral Power, for "VDSL2-NL2" upstream signals (over ISDN), as specified in table 11.

2.2.6. Unbalance about earth (upstream and downstream)

To be compliant with this signal category, the balance of the signal that may flow through the LT-port or NT-port shall exceed minimum requirements, under the condition that the local loop wiring and its termination is well balanced.

The unbalance limits for "VDSL2-NL2" signals are equal to the limits specified before for "VDSL2-NL1" signals.

2.3. "VDSL2-UK1" signals

This category covers signals up to 7,05 MHz, generated by VDSL2 transmission equipment using band plan 997 (limit PSD mask B7-1). These signals may share the same wire pair with POTS signals. This signal description is derived from the ITU VDSL2 recommendation G.993.2 [1]. The downstream signal is enhanced by loop dependent PSD shaping, also known as downstream Power Back-off (DPBO).

- The downstream signal limits are dependent on the *attenuation distance* between the local exchange and cabinet (“primary cable”), defined as downstream power backoff exchange side electrical loss (DPBOESEL) of that loop measured at 300 kHz into a resistive load of 100 Ω.
- The upstream signal limits are dependent on the electrical length of the cable (UPBO, also referred to as kl0) between the cabinet and the customer measured in dB at 1MHz into a resistive load of 100 Ω.

A signal can be classified as a “VDSL2-UK1” signal if it is compliant with all clauses below.

2.3.1. Total signal power (downstream only)

To be compliant with this signal category, the mean downstream signal power into a resistive load of 100 Ω shall not exceed +11,5 dBm.

Reference: ITU- T Recommendation G.993.2 [1], Chapter 6, Table 6-1/G.993.2. Profile 8c.

2.3.2. Total signal power (upstream only)

To be compliant with this signal category, the mean upstream signal power into a resistive load of 100 Ω shall not exceed a level of +14,5 dBm, measured within the frequency bands from 25 kHz to 138 kHz and 2.999 MHz to 5.101MHz.

Reference: ITU- T Recommendation G.993.2 [1], Chapter 6, Table 6-1/G.993.2. Profile 8c.

2.3.3. Peak amplitude (upstream and downstream)

No limit is specified.

NOTE: Peak amplitude is constrained by safety and DC power dissipation considerations.

2.3.4. Narrow-band signal power (downstream only)

To be compliant with this signal category, the Narrow-Band Signal Power (NBSP) into a resistive load impedance ***R*** for a given DBBOESEL-value, shall not exceed the limits given in table 12 and 13, at any point in the frequency range 100 Hz to 30 MHz.

Table 12: Break points of the NBSP limits, of the downstream transmit signal (cabinet PSD mask)

Centre Frequency *f* [MHz]	Impedance R [Ω]	Signal Level P [dBm]	Power Bandwidth B	Spectral Power P/B [dBm/Hz]
0.0001	600	-77.5	100 Hz	-97.5
0.004	600	-77.5	100 Hz	-97.5
0.004	100	-72.5	100 Hz	-92.5
0.08	100	-32.5	10 kHz	-72.5
0.138	100	-9.5	10 kHz	-49.5
0.166	100	-9.5	10 kHz	-49.5
f_1	100	P_1 + 40dB	10 kHz	P_1
f_2	100	P_2+ 40dB	10 kHz	P_2
f_3	100	P_3+ 40dB	10 kHz	P_3
f_4	100	P_4+ 40dB	10 kHz	P_4
f_5	100	P_5+ 40dB	10 kHz	P_5
f_6	100	P_6+ 40dB	10 kHz	P_6
f_7	100	P_7+ 40dB	10 kHz	P_7
f_8	100	P_8+ 40dB	10 kHz	P_8
f_9	100	P_9+ 40dB	10 kHz	P_9
f_{10}	100	P_{10}+ 40dB	10 kHz	P_{10}
f_{11}	100	P_{11}+ 40dB	10 kHz	P_{11}
f_{12}	100	P_{12}+ 40dB	10 kHz	P_{12}
2.208	100	-9.5	10 kHz	-49.5
2.249	100	-9.5	10 kHz	-49.5
2.423	100	-16.5	10 kHz	-56.5
2.999	100	-16.5	10 kHz	-56.5
3	100	-40	10 kHz	-80
3.175	100	-40	1 MHz	-100
4	100	-40	1 MHz	-100
4.001	100	-50	1 MHz	-110
4.924	100	-50	1 MHz	-110
4.925	100	-40	1 MHz	-100
5.099	100	-40	10 kHz	-80
5.1	100	-16.5	10 kHz	-56.5
7.05	100	-16.5	10 kHz	-56.5
7.051	100	-40	10 kHz	-80
7.225	100	-40	1 MHz	-100
7.226	100	-50	1 MHz	-110
30	100	-50	1 MHz	-110

NOTE The limits between breakpoints shall be obtained by interpolation between adjacent breakpoints on a dB/log(f) basis below 3.01 MHz and on a dB/f basis above 3.01 MHz.

Table 13: Definition of parameter f_k and P_k, (with k = 1 to 12), of the downstream NBSP limits in table 12, for DPBOESEL 0 to 52 dB.

DPBOESEL		f_1 P_1	f_2 P_2	f_3 P_3	f_4 P_4	f_5 P_5	f_6 P_6	f_7 P_7	f_8 P_8	f_9 P_9	f_{10} P_{10}	f_{11} P_{11}	f_{12} P_{12}
0	**f**	0.168	2.207	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	P	-49.5	-49.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	**f**	0.168	1.546	1.622	2.207	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	P	-49.5	-49.5	-50.8	-53.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	**f**	0.168	1.346	1.468	1.622	2.207	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	P	-49.5	-49.5	-52.1	-55.2	-58.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	**f**	0.168	1.191	1.25	1.4	1.622	2.207	N/A	N/A	N/A	N/A	N/A	N/A
	P	-49.5	-49.5	-51.0	-54.7	-59.5	-63.4	N/A	N/A	N/A	N/A	N/A	N/A
8	**f**	0.168	0.939	1.104	1.25	1.468	1.622	2.207	N/A	N/A	N/A	N/A	N/A
	P	-49.5	-49.5	-50.6	-54.8	-60.4	-63.9	-68.6	N/A	N/A	N/A	N/A	N/A
10	**f**	0.168	0.582	0.7	0.9	1.104	1.25	1.4	1.622	2.207	N/A	N/A	N/A
	P	-49.5	-49.5	-50.6	-52.4	-54.1	-58.6	-62.7	-68.2	-73.9	N/A	N/A	N/A
12	**f**	0.168	0.372	0.5	0.7	0.9	1.104	1.25	1.4	1.622	1.9	2.207	N/A
	P	-49.5	-49.5	-51.1	-53.4	-55.6	-57.7	-62.3	-66.7	-72.6	-75.8	-79.1	N/A
14	**f**	0.168	0.241	0.3	0.5	0.7	0.9	1.104	1.4	1.622	1.9	2.162	2.207
	P	-49.5	-49.5	-50.5	-53.6	-56.3	-58.8	-61.2	-70.7	-76.9	-80.5	-83.7	-80
16	**f**	0.169	0.199	0.3	0.5	0.7	0.9	1.104	1.25	1.468	1.622	2.11	2.207
	P	-49.8	-50.5	-52.5	-56.0	-59.1	-62.0	-64.7	-69.9	-76.8	-81.3	-88.2	-80
18	**f**	0.173	0.3	0.5	0.7	0.9	1.104	1.4	1.622	1.9	1.994	2.072	2.207
	P	-51.3	-54.5	-58.4	-61.9	-65.1	-68.3	-78.7	-85.6	-90.1	-91.5	-91.5	-80
20	**f**	0.179	0.3	0.5	0.7	1.104	1.4	1.622	1.707	2.072	2.207	N/A	N/A
	P	-53.4	-56.5	-60.9	-64.7	-71.8	-82.7	-90	-91.5	-91.5	-80	N/A	N/A
22	**f**	0.179	0.184	0.3	0.5	0.7	1.104	1.25	1.536	1.869	2.004	2.005	N/A
	P	-53.4	-55.2	-58.5	-63.3	-67.6	-75.3	-81.2	-91.5	-91.5	-80	-49.5	N/A
24	**f**	0.179	0.189	0.3	0.5	0.7	1.104	1.38	1.4	1.468	1.622	1.758	1.759
	P	-53.4	-57.0	-60.5	-65.7	-70.4	-78.8	-90	-90	-91.5	-91.5	-80	-49.5
26	**f**	0.179	0.196	0.3	0.5	0.7	1.104	1.281	1.404	1.448	1.578	1.579	N/A
	P	-53.4	-59.1	-62.5	-68.2	-73.2	-82.4	-90	-90.1	-91.1	-80	-49.5	N/A
28	**f**	0.179	0.199	0.211	0.301	0.5	0.7	0.9	1.104	1.193	1.349	1.468	1.469
	P	-53.4	-60.0	-61.4	-64.5	-70.6	-76.0	-81.1	-85.9	-90	-90	-80	-49.5
30	**f**	0.179	0.199	0.242	0.3	0.5	0.7	0.9	1.115	1.25	1.369	1.370	N/A
	P	-53.4	-60.0	-64.3	-66.5	-73.0	-78.9	-84.2	-90	-90	-80	-49.5	N/A
32	**f**	0.179	0.193	0.199	0.286	0.301	0.5	0.7	0.993	1.162	1.281	1.282	N/A
	P	-53.4	-58.4	-60.0	-68.0	-68.5	-75.5	-81.7	-90	-90	-80	-49.5	N/A
34	**f**	0.179	0.193	0.199	0.264	0.3	0.301	0.5	0.7	0.879	1.083	1.202	1.203
	P	-53.4	-58.4	-60.0	-66.2	-69	-70.5	-77.9	-84.5	-90	-90	-80	-49.5
36	**f**	0.179	0.193	0.199	0.243	0.3	0.301	0.5	0.7	0.781	1.011	1.13	1.132
	P	-53.4	-58.4	-60.0	-64.4	-69	-72.5	-80.3	-87.3	-90	-90	-80	-49.5
38	**f**	0.179	0.193	0.199	0.3	0.301	0.5	0.695	0.7	0.919	1.039	1.04	N/A
	P	-53.4	-58.4	-60.0	-69	-74.5	-82.8	-90	-90	-90	-80	-49.5	N/A
40	**f**	0.179	0.193	0.199	0.3	0.301	0.5	0.621	0.818	0.938	0.939	N/A	N/A
	P	-53.4	-58.4	-60.0	-69	-76.5	-85.2	-90	-90	-80	-49.5	N/A	N/A
42	**f**	0.179	0.193	0.199	0.3	0.301	0.5	0.555	0.728	0.849	0.850	N/A	N/A
	P	-53.4	-58.4	-60.0	-69	-78.5	-87.7	-90	-90	-80	-49.5	N/A	N/A
44	**f**	0.179	0.193	0.199	0.3	0.301	0.5	0.649	0.7	0.771	0.772	N/A	N/A
	P	-53.4	-58.4	-60.0	-69	-79	-90	-90	-85.6	-80	-49.5	N/A	N/A
46	**f**	0.179	0.193	0.199	0.3	0.301	0.5	0.579	0.7	0.701	N/A	N/A	N/A
	P	-53.4	-58.4	-60.0	-69	-79	-90	-90	-80	-49.5	N/A	N/A	N/A
48	**f**	0.179	0.193	0.199	0.3	0.301	0.464	0.5	0.515	0.638	0.639	N/A	N/A
	P	-53.4	-58.4	-60.0	-69	-79	-88.4	-90	-90	-80	-49.5	N/A	N/A
50	**f**	0.179	0.193	0.199	0.3	0.301	0.472	0.5	0.581	0.582	N/A	N/A	N/A
	P	-53.4	-58.4	-60.0	-69	-79	-88.8	-86.4	-80	-49.5	N/A	N/A	N/A
52	**f**	0.179	0.193	0.199	0.3	0.301	0.452	0.551	0.552	N/A	N/A	N/A	N/A
	P	-53.4	-58.4	-60.0	-69	-79	-87.8	-80	-49.5	N/A	N/A	N/A	N/A

NOTE-1: The label “N/A” denotes that a breakpoint is not used.

NOTE-2: If the parameter DPBOESEL is greater than 52 dB, the values associated with 52 apply for this signal description.

The PSD of the downstream signal description changes with the downstream power back-off exchange side electrical loss (DPBOESEL). Examples are shown in figure 9 for different values for DPBOESEL.
In practice, where multiple paths with different loss values exist between exchange and cabinet, a compromise DPBOESEL value is commonly selected to cause similar fractional harm to exchange based and cabinet based services.

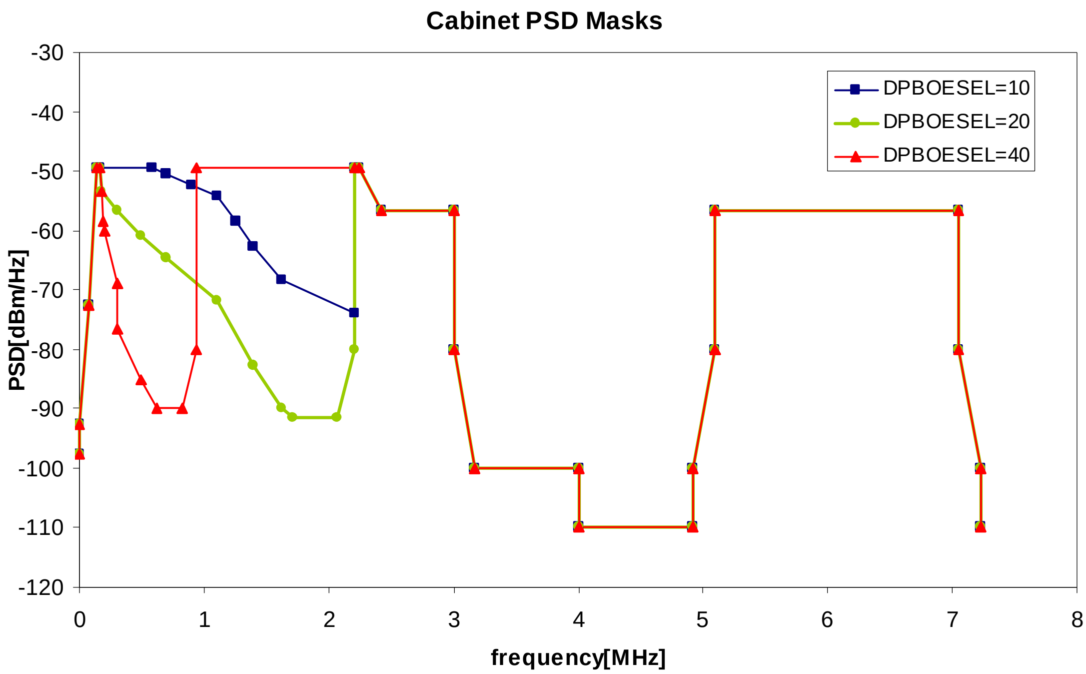

Figure 9: Spectral power for "VDSL2-UK1" downstream signals, as specified in table 12 and 13, for different values of DPBOESEL.

2.3.5. Narrow-band signal power (upstream only)

To be compliant with this signal category, the Narrow-Band Signal Power (NBSP) into a resistive load impedance ***R*** for a given UPBO-value, shall not exceed the limits given in table 14 and 15, at any point in the frequency range 100 Hz to 30 MHz.

Table 14: Break points of the NBSP limits, of the upstream transmit signal (customer PSD mask)

Centre Frequency *f* [MHz]	Impedance R [Ω]	Signal Level P [dBm]	Power Bandwidth B	Spectral Power P/B [dBm/Hz]
0.0001	600	-77.5	100 Hz	-97.5
0.004	600	-77.5	100 Hz	-97.5
0.004	100	-72.5	100 Hz	-92.5
0.026	100	5.5	10 kHz	-34.5
0.138	100	5.5	10 kHz	-34.5
0.243	100	-53.2	10 kHz	-93.2
0.686	100	-60	10 kHz	-100
2.825	100	-60	10 kHz	-100
2.999	100	P_1+ 40dB	10 kHz	P_1
3	100	P_2+ 40dB	10 kHz	P_2
4	100	P_3+ 40dB	10 kHz	P_3
5.1	100	P_4+ 40dB	10 kHz	P_4
5.101	100	P_5+ 40dB	10 kHz	P_5
5.275	100	-60	10 kHz	-100
5.276	100	-70	10 kHz	-110
5.776	100	-50	1 MHz	-110
30	100	-50	1 MHz	-110

NOTE The limits between breakpoints shall be obtained by interpolation between adjacent breakpoints on a dB/log(f) basis below 2.825 MHz and on a dB/f basis above 2.825 MHz. The values above and including 2.825 MHz are according to ITU- T Recommendation G.993.2 [1].

Table 15: Definition of parameter P_k, (with k = 1 to 6), of the upstream NBSP limits in table 14, for UPBO 0 to 17 dB.

UPBO	P_1	P_2	P_3	P_4	P_5
0	-85.9	N/A	-90.5	N/A	-94.9
1	-84.2	N/A	-88.5	N/A	-92.6
2	-82.5	N/A	-86.5	N/A	-90.4
3	-80.7	N/A	-84.5	N/A	-88.1
4	-80	-79	-82.5	N/A	-85.9
5	-80	-77.3	-80.5	N/A	-83.6
6	-80	-75.6	-78.5	N/A	-81.3
7	-80	-73.8	-76.5	-79.1	-80
8	-80	-72.1	-74.5	-76.8	-80
9	-80	-70.4	-72.5	-74.6	-80
10	-80	-68.6	-70.5	-72.3	-80
11	-80	-66.9	-68.5	-70	-80
12	-80	-65.2	-66.5	-67.8	-80
13	-80	-63.4	-64.5	-65.5	-80
14	-80	-61.7	-62.5	-63.3	-80
15	-80	-60	-60.5	-61	-80
16	-80	-58.2	-58.5	-58.8	-80
17	-80	-56.5	-56.5	-56.5	-80

NOTE Note that the effective range of UPBO is limited to 0 to 17 dB. Values of UPBO in excess of 17 dB do not result in an increased mask. Within these bounds any value of UPBO may be used

The PSD of the upstream signal description changes with the upstream valus for UPBO. Examples are shown in figure 10, for different values for UPBO, ranging from 0 to 17 dB.

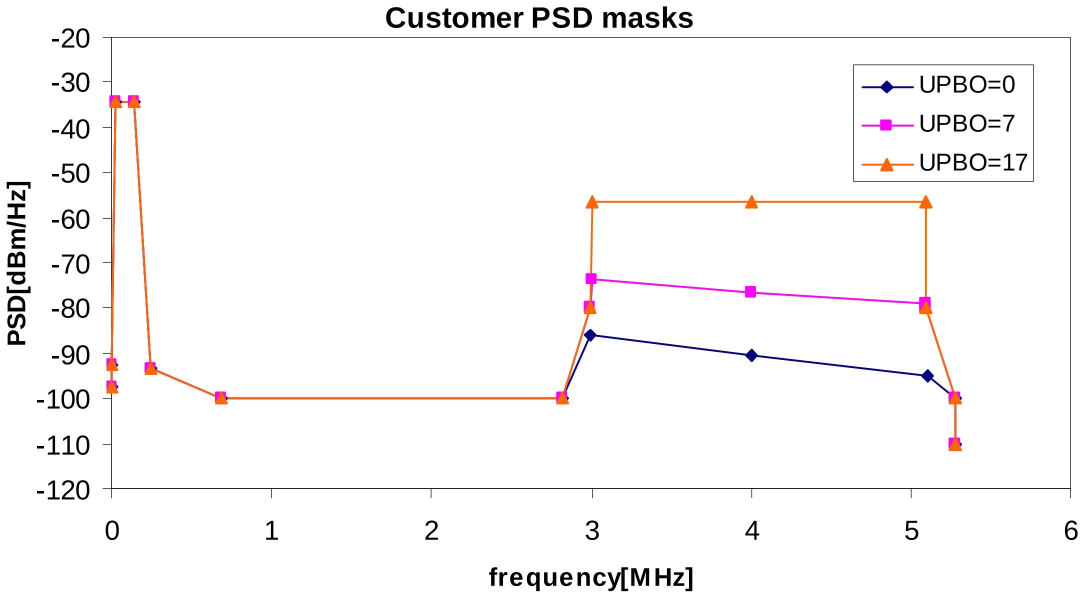

Figure 10: Spectral power for "VDSL2-UK1" upstream signals, as specified in table 14 and 15, for different values of UPBO,

2.3.6. Unbalance about earth (upstream and downstream)

To be compliant with this signal category, the unbalance about earth shall not exceed the associated limits specified for "VDSL2-NL1" signals.