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Spectrum Management and Telecommunications

Compliance Specification for Terminal Equipment, Terminal Systems, Network Protection Devices, Connection Arrangements and Hearing Aids Compatibility

Part VIII: Requirements and Test Methods for Digital Subscriber Line (xDSL) Terminal Equipment

Aussi disponible en français - SC-03 Partie VIII

Canada

Contents

1.0 Introduction

1.1 Scope

This part sets forth the minimum network protection requirements for:

- Asymmetrical Digital Subscriber Line terminal equipment (TE) using either Carrierless Amplitude Phase modulation or Discrete Multi-Tone technology;

- Asymmetrical Digital Subscriber Line transceivers -2 (ADSL2);

- Asymmetrical Digital Subscriber Line transceivers - Extended Bandwidth ADSL2 (ADSL2+);

- Reach Extend Asymmetrical Digital Subscriber Line transceivers (READSL);

- High bit rate Digital Subscriber Line TE using either Carrierless Amplitude Phase modulation or “2 Binary 1 Quaternary” line code (**HDSL** [CAP/2B1Q]);

- High bit rate Digital Subscriber Line 2nd generation TE using Trellis Coded Pulse Amplitude Modulation (**HDSL2** [TC-PAM]);

- Symmetrical Digital Subscriber Line TE using “2 Binary 1 Quaternary” line code (**SDSL** [2B1Q]);

- Single pair High-Speed Digital Subscriber Line TE using Trellis Coded Pulse Amplitude Modulation (**SHDSL** [G.shdsl - TC-PAM]);

- 4-wire High bit rate Digital Subscriber Line 2nd generation TE using Trellis Coded Pulse Amplitude Modulation (**HDSL4** [TC-PAM]);

- Very-high-bit-rate Digital Subscriber Line (VDSL) terminal equipment using either a single-carrier modulation (QAM) or a multi-carrier modulation (DMT).

- Very high-speed digital subscriber line2 (VDSL2) terminal equipment using discrete multi-tone (DMT) modulation.

ADSL equipment uses one cable pair where transmission of voice band signals and data can occur simultaneously. Asymmetric transmission of data provides a high bit rate downstream (towards the subscriber) and a lower bit rate upstream (towards the central office). Refer to Figure 1.1 for the ADSL functional reference model.

ADSL2 equipment uses one cable pair and allows high-speed data transmission between the network operator end (ATU-C) and the customer end (ATU-R). Refer to Figure 1.1 for the ADSL2 functional reference model.

HDSL equipment provides equal bit rate in both directions (downstream and upstream). Both channels can be supported on the same cable pair (1 pair HDSL) or one channel per cable pair (2 pair HDSL).

Two HDSL channels are equivalent to a T1 structure. Baseband voice signals cannot be carried simultaneously with data. Refer to Figure 1.2 for the HDSL reference model.

HDSL2 is a second generation HDSL loop transmission system that is standardized. The system is designed to transport a 1.544 Mbps payload on a single non-loaded twisted pair at carrier serving area distances. Refer to Figure 1.2 for the HDSL2 reference model.

2B1Q SDSL has the same symbol rate, baud rate, and power spectral density at both STU-C and STU-R transceivers. 2B1Q SDSL system may vary its data rate from 64 kbps to 2320 kbps. Refer to Figure 1.2 for the 2B1Q SDSL reference model. Typically, 2B1Q SDSL equipment transmits a symmetric signal on a single copper pair.

SHDSL uses Trellis Coded Pulse Amplitude Modulation (TC-PAM) on a single copper pair to transmit a symmetric signal with data rates from 192 kbps to 2.312 Mbps. Refer to Figure 1.2 for the SHDSL reference model.

HDSL4 is a variant of SHDSL, using TC-PAM on 2 copper pairs (4 wires) to transmit an asymmetric signal with a data rate of 768/776 kbps. Refer to Figure 1.2 for the HDSL4 reference model.

VDSL is an xDSL technology designed to support very-high-speed data transmission over relatively short twisted-pair loops, which simultaneously support POTS (plain old telephone service). The system will support both symmetric and asymmetric data transmission with payload rates as described in Table 1.1.

VDSL2 is an enhancement to VDSL that supports asymmetric and symmetric transmission at a bidirectional net data rate up to 200 Mbit/s on twisted pairs using a bandwidth up to 30 MHz.

Table 1.1: Service Types and Data Rates

Service Type	Downstream Data Rate (Mbps)	Upstream Data Rate (Mbps)
Asymmetric	22	3
Symmetric	6	6
	13	13

Note: Table 1.1 above represents the minimum payload rates for VDSL transmission. The actual equipment may support other rates.

The term xDSL is used in this document to refer generically to any of the digital subscriber line variants.

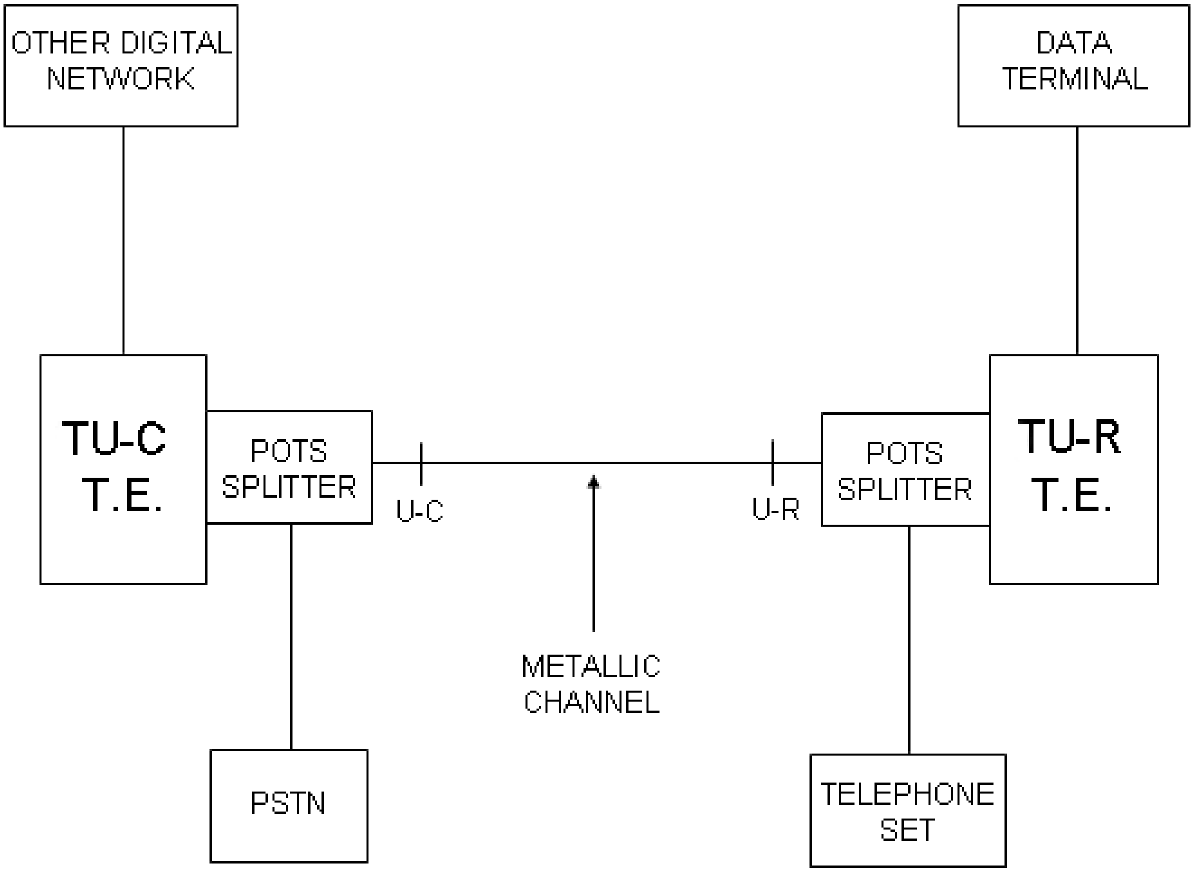


**Figure 1.1: TE Functional Reference Model
for ADSL, ADSL2, ADSL2+, READSL, VDSL and VDSL2**

Note: TU-C = ADSL/ADSL2/ADSL2+/READSL/VDSL/VDSL2 transceiver unit, central office end
TU-R = ADSL/ADSL2/ADSL2+/READSL/VDSL/VDSL2 transceiver unit, remote terminal end
PSTN = Public Switched Telephone Network
POTS = Plain Old Telephone Service

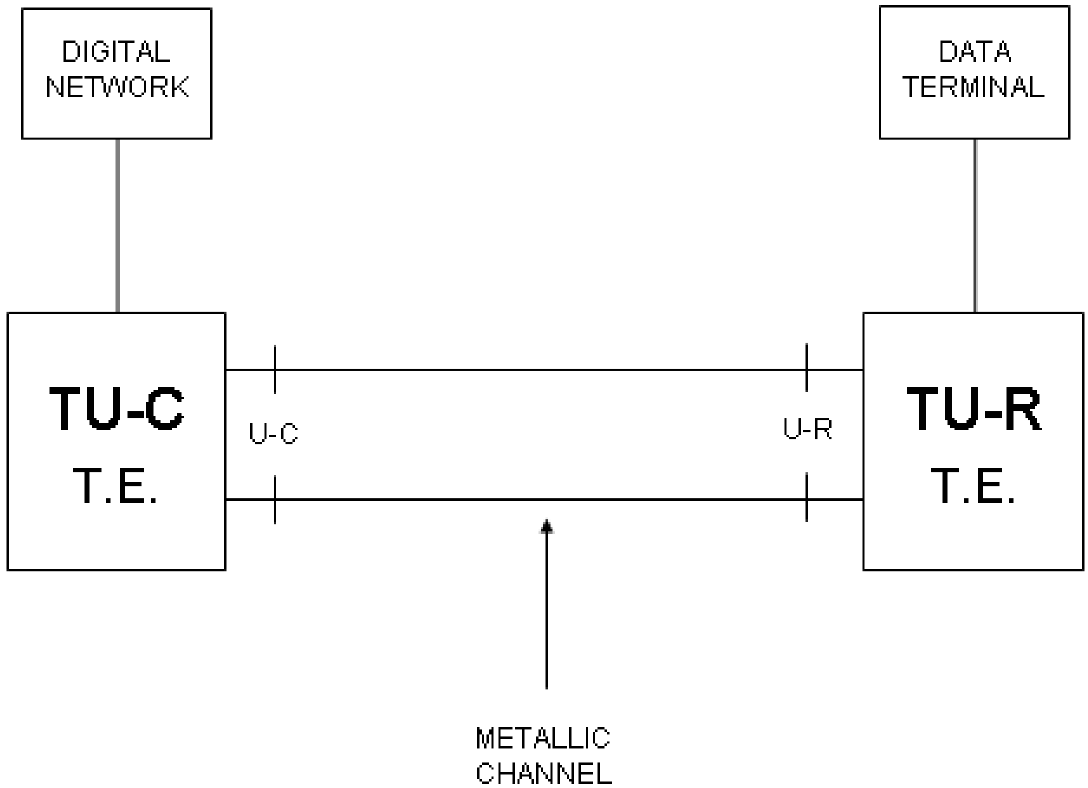


Figure 1.2: TE Functional Reference Model for HDSL, HDSL2, SDSL, SHDSL, and HDSL4

Note: TU-C = HDSL/HDSL2/SDSL/SHDSL/HDSL4 transceiver unit, central office end
TU-R = HDSL/HDSL2/SDSL/SHDSL/HDSL4 transceiver unit, remote terminal end

1.2 Technical Requirements

XDSL terminal equipment connected to the U-R interface shall comply with the following technical requirements.

Table 1.2: Technical Requirements Table

Section	Technical Requirements
2	Electrical and Mechanical Stresses
3.2	Transmitted Spectral Response
3.3	Total Signal Power
3.4	Transverse Balance
3.5	Longitudinal Output Voltage

1.3 Sequence of Equipment Testing

The tests shall be performed in the following order:

(1) Section 1.4 Connecting Arrangements
(2) Section 1.5 Operational Check
(3) Section 2.2 (Part I) Dielectric Strength
(4) Section 2.3 (Part I) Hazardous Voltage Limitations (As applicable)
(5) Section 3.0 Network Protection Requirements and Tests
(6) Section 2.1 (Part I) Mechanical Shock
(7) Section 2.4 (Part I) Surge Voltage
(8) Section 2.5 (Part I) Power Line Surge
(9) Section 1.5 Operational Check
(10) Section 2.2 (Part I) Dielectric Strength
(11) Section 2.3 (Part I) Hazardous Voltage Limitations (As applicable)
(12) Section 3.0 Network Protection Requirements and Tests

1.4 Connecting Arrangements

Cords and plugs of xDSL TE intended for direct electrical connection to the public switched network shall comply with Part III.

1.5 Operational Check

When the operational checks are performed before the application of electrical stress, the TE shall be fully operational, in accordance with the manufacturer's operating instructions, for those features necessary to allow demonstration of compliance with all applicable requirements of Section 3.0. When the operational checks are repeated after the electrical stress of Section 2.0, it is permissible that the TE be partially or fully inoperable.

2.0 Electrical and Mechanical Stresses

The technical requirements and methods of application for electrical and mechanical stresses are given in Part I, Section 2.0.

3.0 Network Protection Requirements and Test Methods

3.1 Laboratory Environment

All tests to determine compliance with these requirements shall be conducted in a laboratory environment at normal room temperature and humidity.

3.2 Transmitted Spectral Response

3.2.1 Requirements

3.2.1.1 Power Spectral Density at the U-R Interface for ADSL

The Power Spectral Density (PSD) of the signal transmitted over the ADSL **upstream** channel (ATU-R output) shall not exceed the PSD mask in Figure 3.2.1.1. Table 3.2.1.1 provides the numerical values for the mask.

Table 3.2.1.1: ATU-R PSD Mask Definition for ADSL

Frequency Band (kHz)	PSD (dBm/Hz) across 100 ohms
$0.2 < f \leq 4$	-97.5
$4 < f \leq 25.875$	$-92.5 + 21.5 \times \log_2(f/4)$
$25.875 < f \leq 138$	-34.5
$138 < f \leq 307$	$-34.5 - 48 \times \log_2(f/138)$
$307 < f \leq 1221$	-90
$1221 < f \leq 1630$	-90 peak, with max power in the [f, f + 1 MHz] window of ($-90 - 48 \times \log_2(f/1221) + 60$) dBm
$1630 < f \leq 30000$	-90 peak, with max power in the [f, f + 1 MHz] window of -50 dBm

Note 1: The breakpoint frequencies and PSD values are exact.

Note 2: Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth. Below 25.875 kHz, the peak PSD shall be measured with a 100 Hz resolution bandwidth.

Note 3: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.

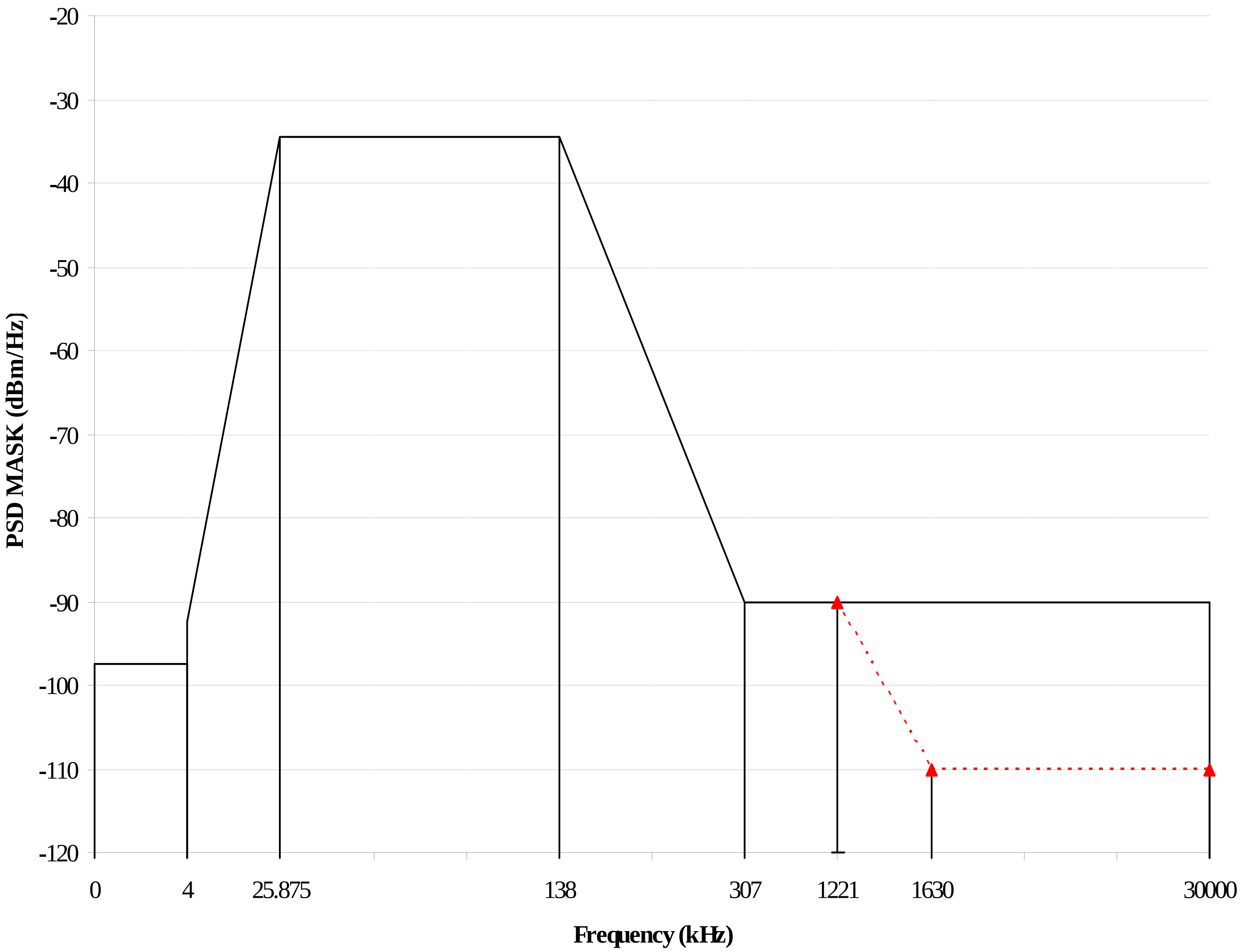


Figure 3.2.1.1: ATU-R Upstream Transmission PSD Mask for ADSL

3.2.1.2 Power Spectral Density at the U-R Interface for ADSL2

Table 3.2.1.2: ATU-R PSD Mask Definition for ADSL2

Frequency Band (kHz)	PSD (dBm/Hz) across 100 ohms
$0.2 < f \leq 1.5$	-46.5
$1.5 < f \leq 3$	$-34.5 + 12 \times \log_2(f/3)$
$3 < f \leq 138$	-34.5
$138 < f \leq 307$	$-34.5 - 48 \times \log_2(f/138)$
$307 < f \leq 1221$	-90 peak, with max power in the [*f*, *f* + 100 kHz] window of -42.5 dBm
$1221 < f \leq 1630$	-90 peak, with max power in the [*f*, *f* + 1 MHz] window of $(-90 - 48 \times \log_2(f/1221) + 60)$ dBm
$1630 < f \leq 30000$	-90 peak, with max power in the [*f*, *f* + 1 MHz] window of -50 dBm

Note 1: The breakpoint frequencies and PSD values are exact.

Note 2: Above 3 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth. Below 3 kHz, the peak PSD shall be measured with a 100 Hz resolution bandwidth.

Note 3: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.

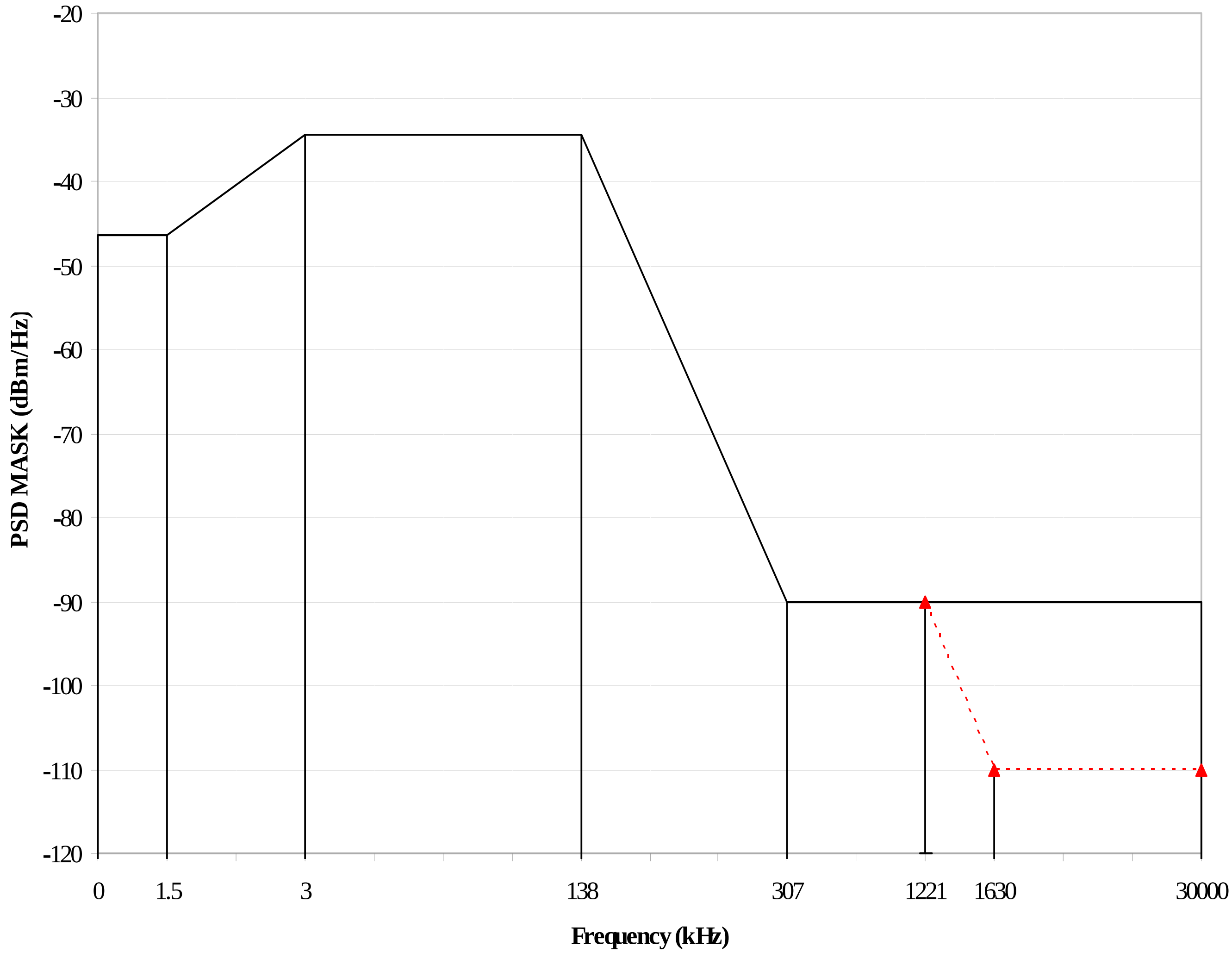


Figure 3.2.1.2: ATU-R Upstream Transmission PSD Mask for ADSL2 All Digital Mode

3.2.1.3 Power Spectral Density at the U-R Interface for ADSL2 All Digital Mode Spectral Compatibility with ISDN

Table 3.2.1.3(a): ATU-R PSD Mask Definition for ADSL2

Frequency Band (kHz)	PSD (dBm/Hz) across 100 ohms
$0.2 < f \leq 1.5$	-46.5
$1.5 < f \leq 3$	$-46.5 + (\text{inband peak PSD} + 46.5) \times \log_2(f/1.5)$
$3 < f \leq f1$	inband peak PSD
$f1 < f \leq f2$	$\text{inband peak PSD} - 48 \log_2(f/f1)$
$f2 < f \leq 1221$	-90
$1221 < f \leq 1630$	-90 peak, with max power in the [f, f + 1 MHz] window of $(-30 - 48 \times \log_2(f/1221))$ dBm
$1630 < f \leq 30000$	-90 peak, with max power in the [f, f + 1 MHz] window of -50 dBm

Note 1: The breakpoint frequencies and PSD values are exact.

Note 2: Above 3 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.

Note 3: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.

Table 3.2.1.3(b): ATU-R Inband peak PSD Mask Designator for ADSL2

Designator	Inband peak PSD (dBm/Hz)	Frequency *f*1 (kHz)	Frequency *f*2 (kHz)
ADLU - 32	-34.5	138	307
ADLU - 36	-35	155.25	343
ADLU - 40	-35.5	172.5	379
ADLU - 44	-35.9	189.75	415
ADLU - 48	-36.3	207	450
ADLU - 52	-36.6	224.25	485
ADLU - 56	-36.9	241.5	520
ADLU - 60	-37.2	258.75	554
ADLU - 64	-37.5	276	589

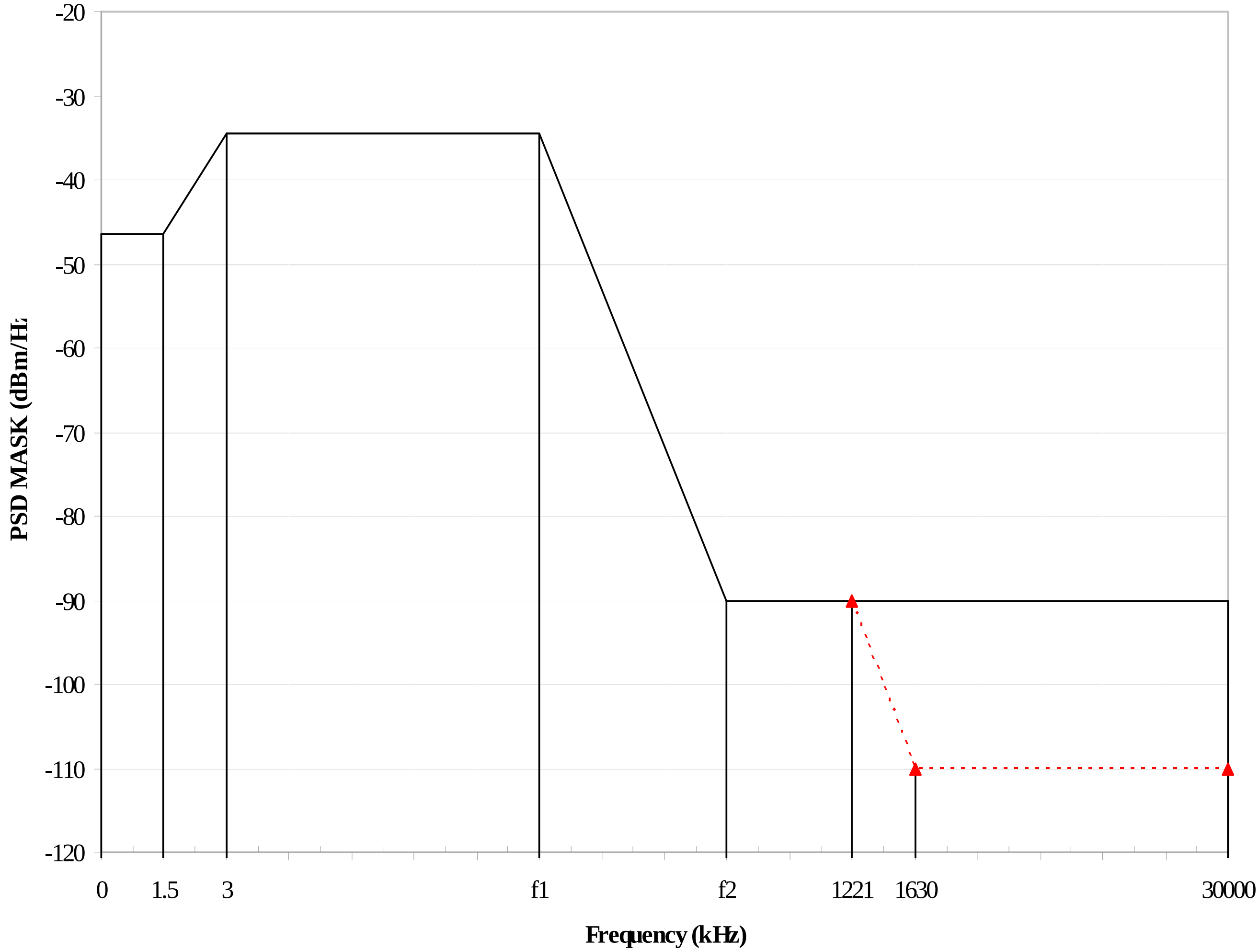


Figure 3.2.1.3(a): ATU-R Upstream Transmission PSD Mask for ADSL2 All Digital Mode

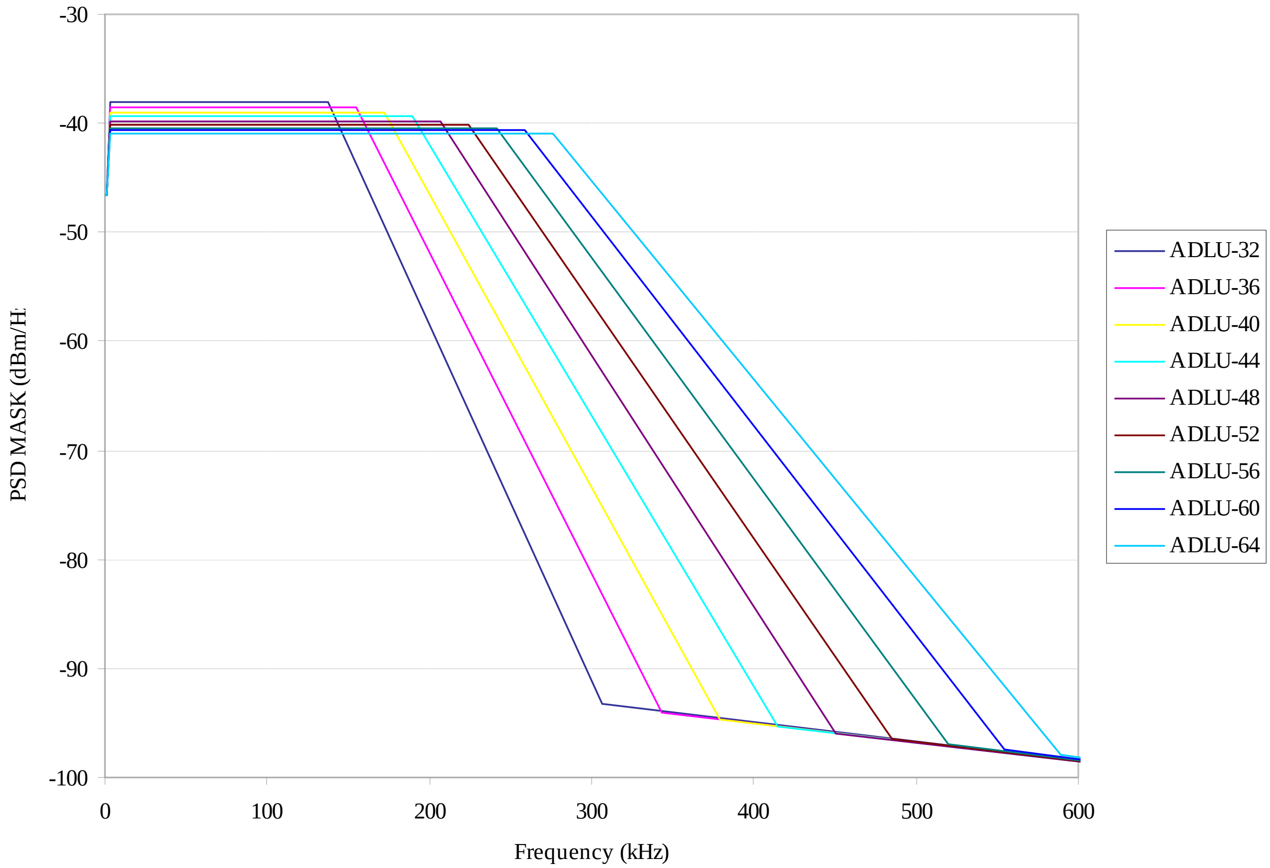


Figure 3.2.1.3(b): ATU-R Upstream Transmission PSD Designator for ADSL2 All Digital Mode

3.2.1.4 Power Spectral Density at the U-R Interface for ADSL2 READSL

The Power Spectral Density (PSD) of the signal transmitted over the ADSL2 READSL upstream channel (ATU-R output) shall comply with either of the following PSD masks: Mask 1 given in Figure 3.2.1.4(a); or Mask 2 given in Figure 3.2.1.4(b). Table 3.2.1.4(a) provides the numerical values for Mask 1, and Table 3.2.1.4(b) provides the numerical values for Mask 2.

Table 3.2.1.4(a): ATU-R PSD Mask 1 Definition

Frequency Band (kHz)	PSD (dBm/Hz) across 100 ohms
$0.2 < f \leq 4$	-97.5, with max power in the 0-4 kHz band of +15 dBm
$4 < f \leq 25.875$	$-92.5 + 22.13 \times \log_2(f/4)$
$25.875 < f \leq 103.5$	-32.9
$103.5 < f \leq 686$	$\max\{-32.9 - 72 \times \log_2 (f/103.5), 10 \times \log_{10}[0.05683 \times (f\text{x}10^3)^{-1.5}]\}$
$686 < f \leq 1411$	-100
$1411 < f \leq 1630$	-100 peak, with max power in the [f, f + 1 MHz] window of $(-110 - 48 \times \log_2(f/1411) + 60)$ dBm
$1630 < f \leq 5275$	-100 peak, with max power in the [f, f + 1 MHz] window of $(-110 - 1.18 \times \log_2(f/1630) + 60)$ dBm
$5275 < f \leq 30000$	-100 peak, with max power in the [f, f + 1 MHz] window of -52 dBm

Table 3.2.1.4(b): ATU-R PSD Mask 2 Definition

Frequency Band (kHz)	PSD (dBm/Hz) across 100 ohms
$0.2 < f \leq 4$	-97.5, with max power in the 0-4 kHz band of +15 dBm
$4 < f \leq 25.875$	$-92.5 + 23.43 \times \log_2(f/4)$
$25.875 < f \leq 60.375$	-29.4
$60.375 < f \leq 686$	$\max\{-29.4 - 72 \times \log_2 (f/60.375), 10 \times \log_{10}[0.05683 \times (f\text{x}10^3)^{-1.5}]\}$
$686 < f \leq 1411$	-100
$1411 < f \leq 1630$	-100 peak, with max power in the [f, f + 1 MHz] window of $(-110 - 48 \times \log_2(f/1411) + 60)$ dBm
$1630 < f \leq 5275$	-100 peak, with max power in the [f, f + 1 MHz] window of $(-110 - 1.18 \times \log_2(f/1630) + 60)$ dBm
$5275 < f \leq 30000$	-100 peak, with max power in the [f, f + 1 MHz] window of -52 dBm

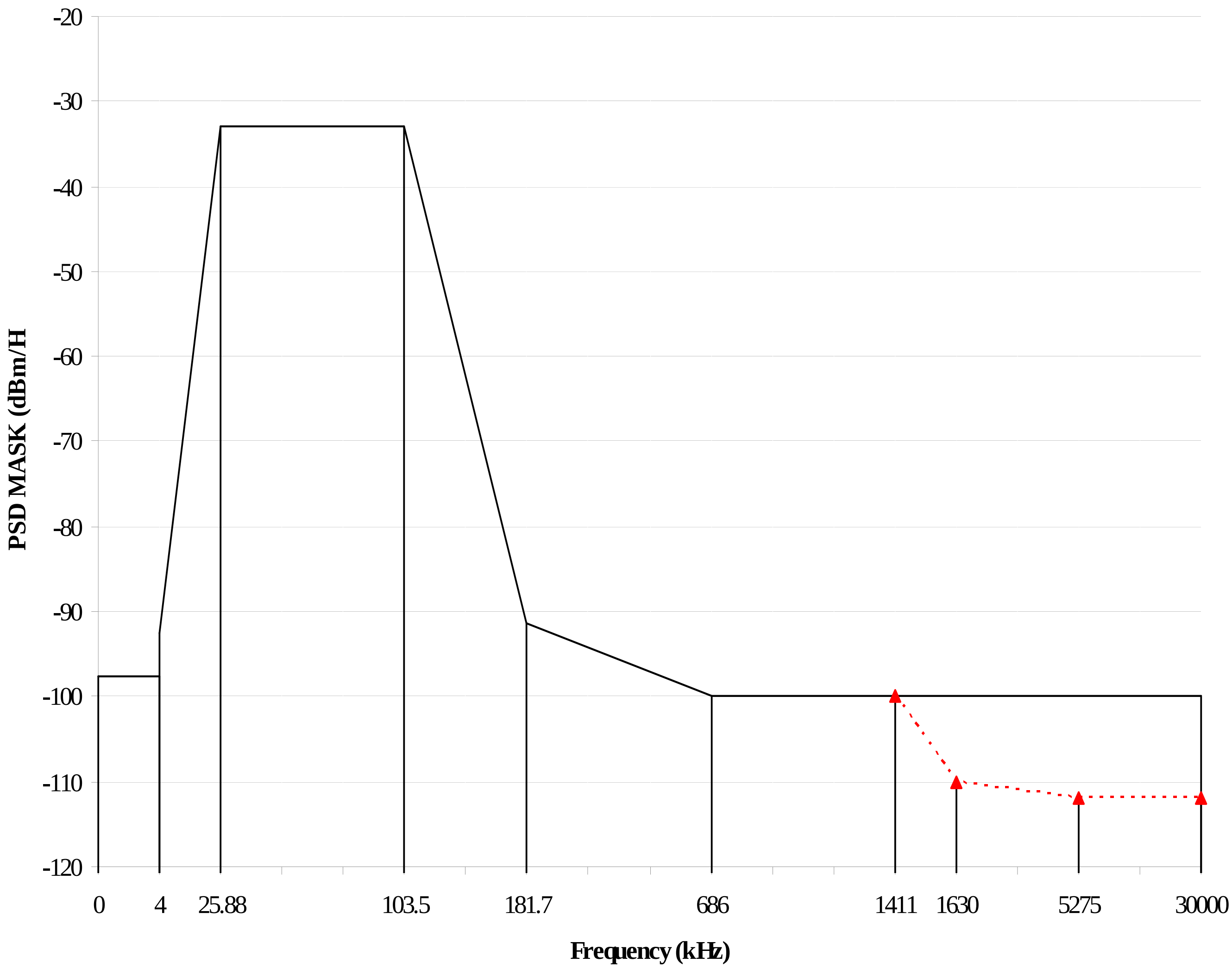


Figure 3.2.1.4(a): ATU-R Upstream Transmission PSD Mask 1 for ADSL2 READSL

Note 1: The breakpoint frequencies and PSD values are exact.

Note 2: Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth. Below 25.875 kHz, the peak PSD shall be measured with a 100 Hz resolution bandwidth.

Note 3: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.

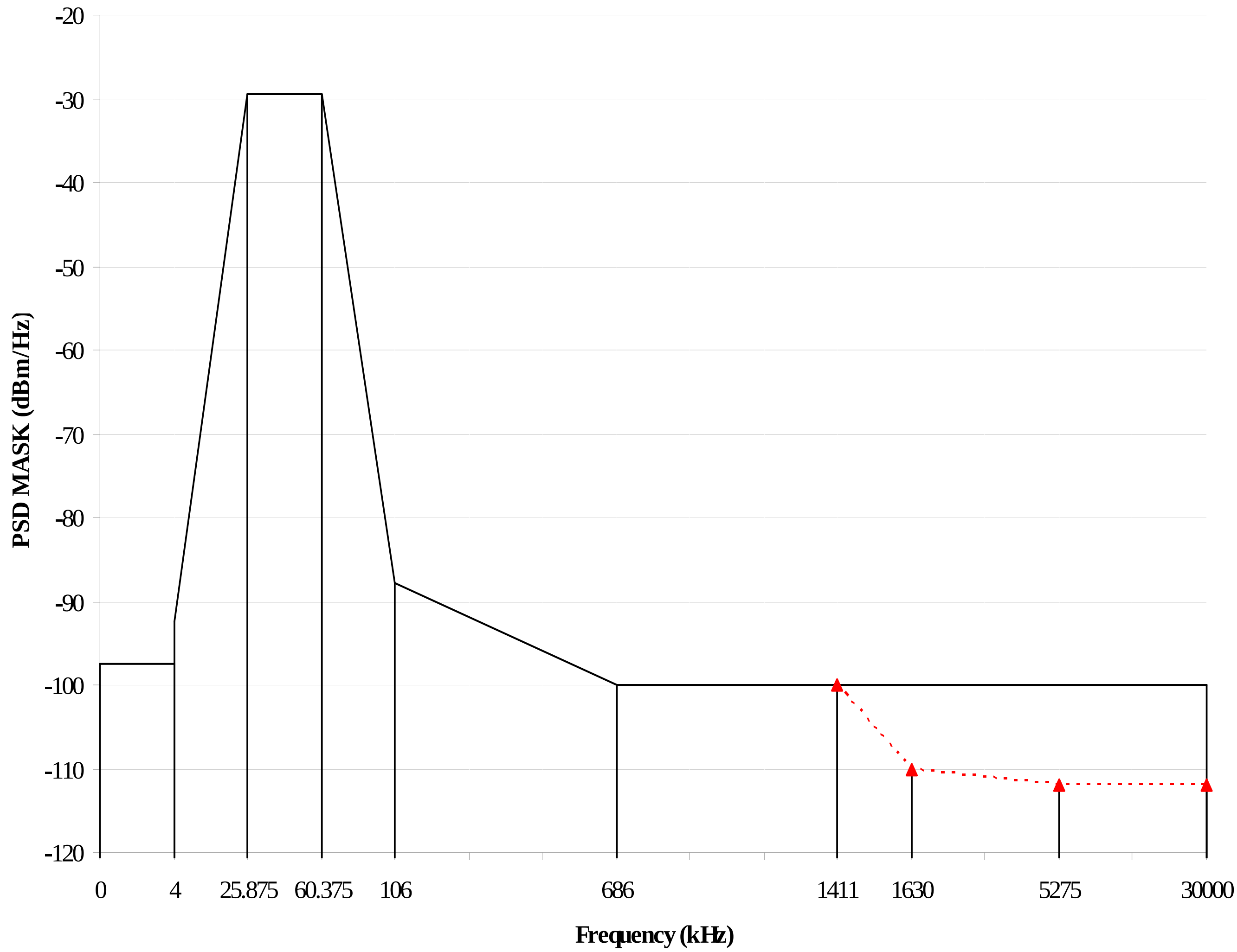


Figure 3.2.1.4(b): ATU-R Upstream Transmission PSD Mask 2 for ADSL2 READSL

Note 1: The breakpoint frequencies and PSD values are exact.

Note 2: Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth. Below 25.875 kHz, the peak PSD shall be measured with a 100 Hz resolution bandwidth.

Note 3: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.

3.2.1.5 Power Spectral Density at the U-R Interface for ADSL2 with Extended Upstream above POTS

Table 3.2.1.5(a): ATU-R PSD Mask Definition (ADSL2 with Extended Upstream above POTS)

Frequency (kHz)	PSD (dBm/Hz) across 100 ohms
0.2	-97.5
4	-97.5
4	-92.5
25.875	inband peak PSD
*f*1	inband peak PSD
*f*int	PSD int
686	-100
1411	-100 with a 1 MHz measurement bandwidth
1630	-110 with a 1 MHz measurement bandwidth
5275	-100 with a 10 kHz measurement bandwidth and -112 with a 1 MHz measurement bandwidth
30000	-100 with a 10 kHz measurement bandwidth and -112 with a 1 MHz measurement bandwidth

Note 1: The breakpoint frequencies and PSD values are exact.

Note 2: Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.

Note 3: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.

Table 3.2.1.5(b): ATU-R Inband Peak PSD Mask Designator (ADSL2 with Extended Upstream above POTS)

Designator	Inband peak PSD (dBm/Hz)	Frequency *f*1 (kHz)	Frequency *f*int (kHz)	Intercept PSD (dBm/Hz)
EU - 32	-34.5	138	242.92	-93.2
EU - 36	-35	155.25	274	-94
EU - 40	-35.5	172.5	305.16	-94.7
EU - 44	-35.9	189.75	336.4	-95.4
EU - 48	-36.3	207	367.69	-95.9
EU - 52	-36.6	224.25	399.04	-96.5
EU - 56	-36.9	241.5	430.45	-97
EU - 60	-37.2	258.75	461.9	-97.4
EU - 64	-37.5	276	493.41	-97.9

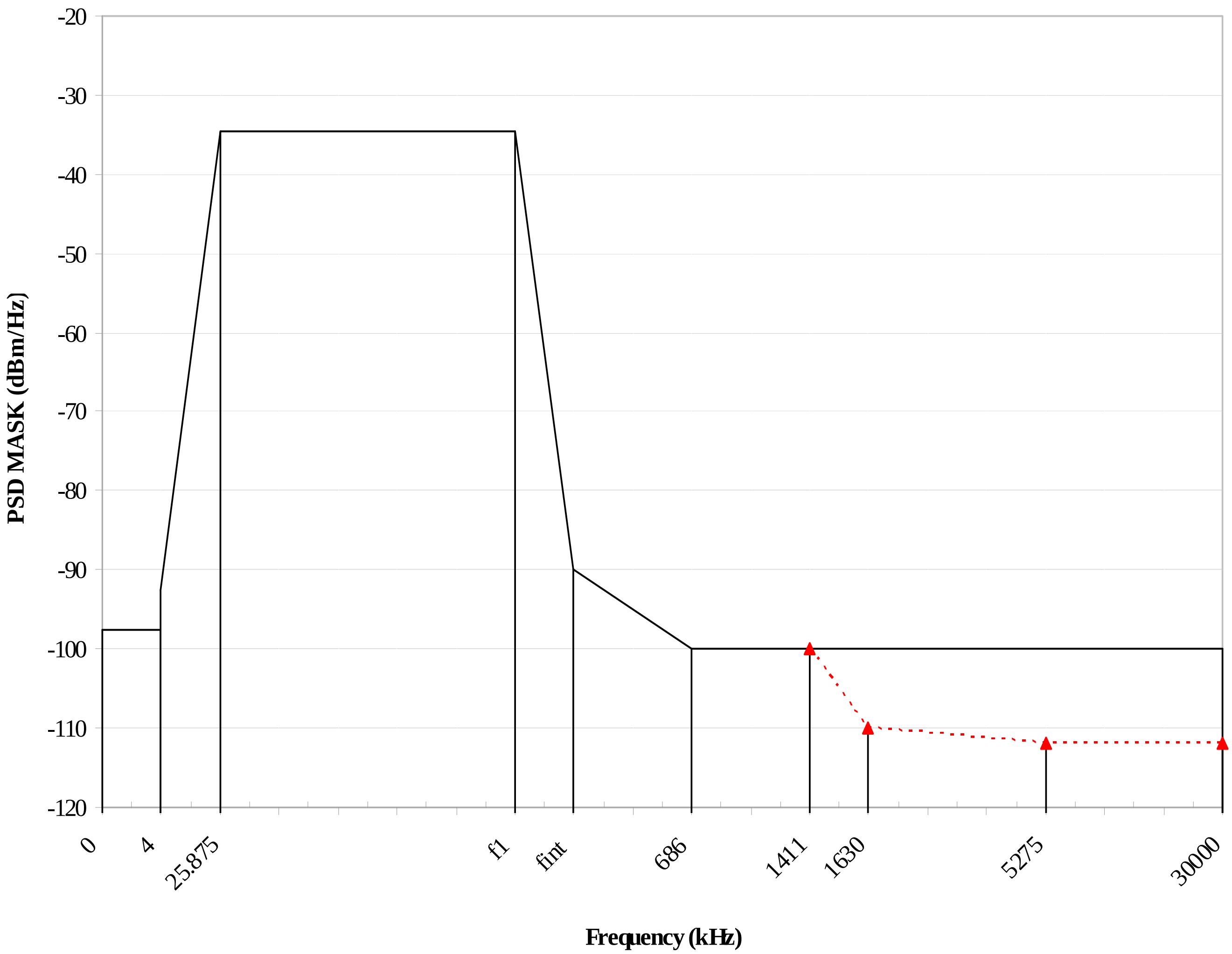


Figure 3.2.1.5(a): ATU-R Upstream Transmission PSD Mask for ADSL2 Extended Upstream above POTS

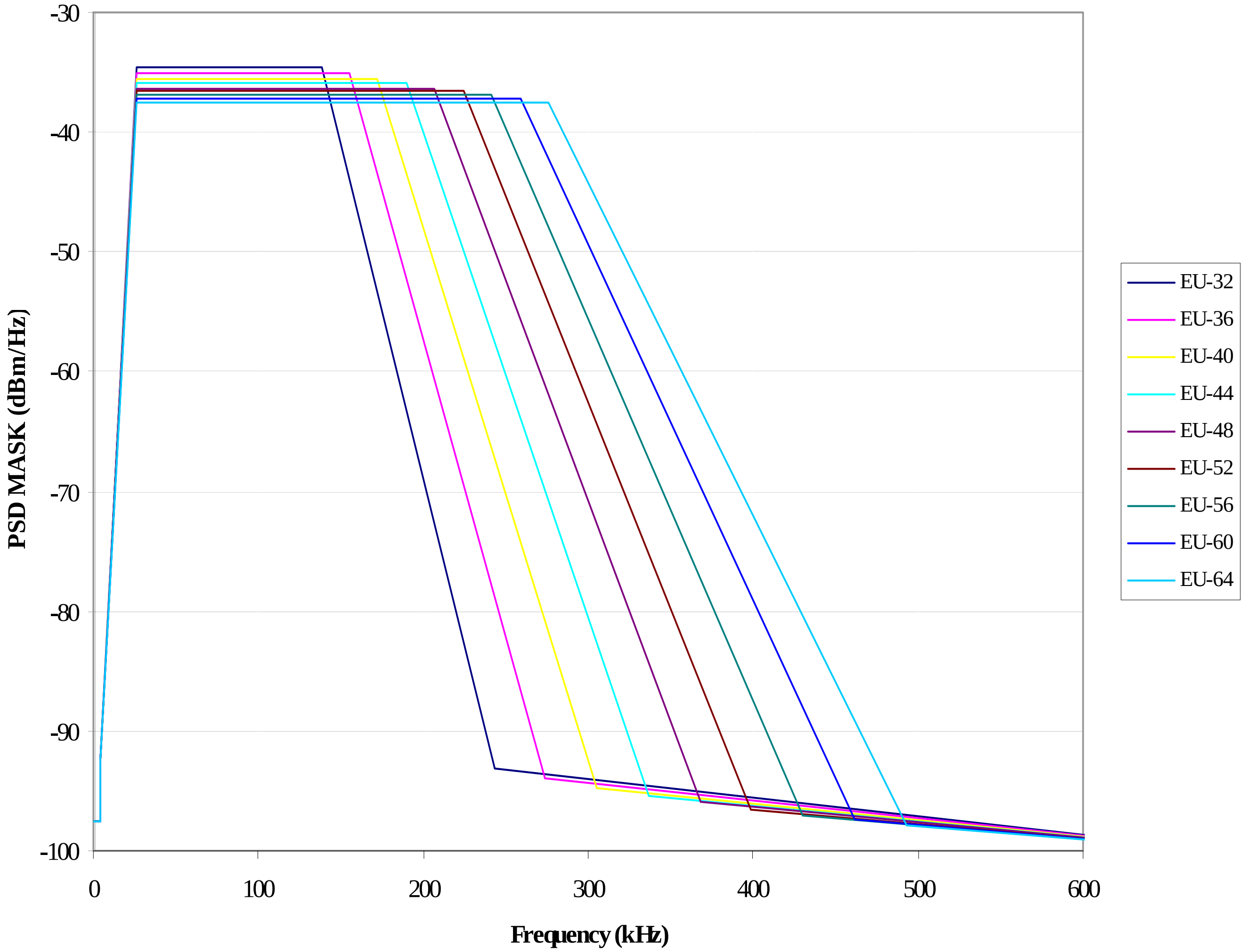


Figure 3.2.1.5(b): ATU-R Upstream Transmission PSD Mask Designator for ADSL2 Extended Upstream above POTS

3.2.1.6 Power Spectral Density at the U-R Interface for ADSL2+ All Digital Mode

Table 3.2.1.6(a): ATU-R PSD Mask Definition (ADSL2+ All Digital Mode)

Frequency (kHz)	PSD (dBm/Hz) across 100 ohms
0.2	-46.5
1.5	-46.5
3	inband peak PSD
*f*1	inband peak PSD
*f*int	PSD int
686	-100
1411	-100 with 10 kHz and 1 MHz measurement bandwidths
1630	-100 with a 10 kHz measurement bandwidth and -110 with a 1 MHz measurement bandwidth
5275	-100 with a 10 kHz measurement bandwidth and -112 with a 1 MHz measurement bandwidth
30000	-100 with a 10 kHz measurement bandwidth and -112 with a 1 MHz measurement bandwidth

Note 1: The breakpoint frequencies and PSD values are exact.

Note 2: Above *f*1 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.

Note 3: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.

Table 3.2.1.6(b): ATU-R Inband Peak PSD Mask Designator (ADSL2+ All Digital Mode)

Designator	Inband peak PSD (dBm/Hz)	Frequency *f*1 (kHz)	Frequency *f*int (kHz)	Intercept PSD (dBm/Hz)
ADLU - 32	-34.5	138	242.92	-93.2
ADLU - 36	-35	155.25	274	-94
ADLU - 40	-35.5	172.5	305.16	-94.7
ADLU - 44	-35.9	189.75	336.4	-95.4
ADLU - 48	-36.3	207	367.69	-95.9
ADLU - 52	-36.6	224.25	399.04	-96.5
ADLU - 56	-36.9	241.5	430.45	-97
ADLU - 60	-37.2	258.75	461.9	-97.4
ADLU - 64	-37.5	276	493.41	-97.9

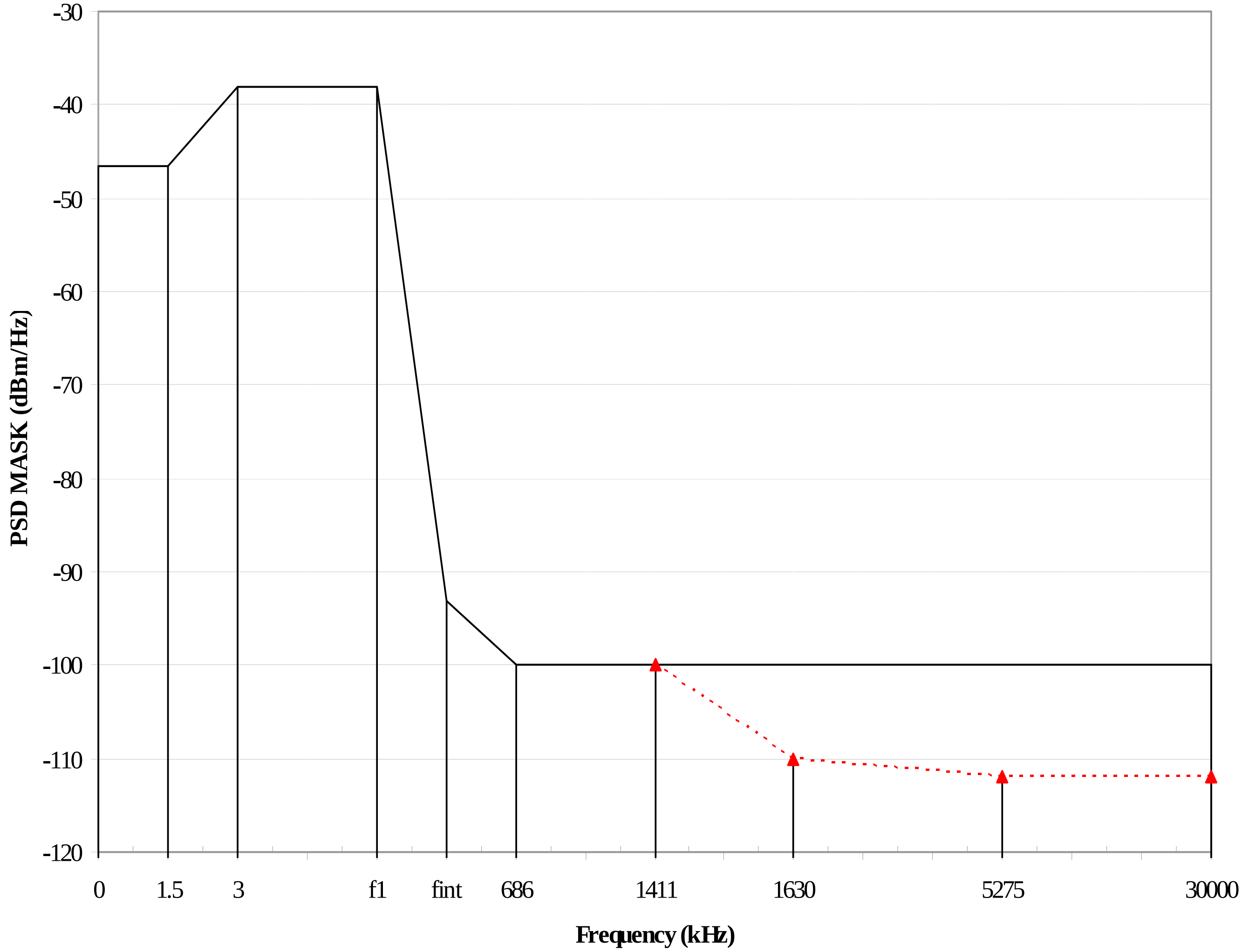


Figure 3.2.1.6(a): ATU-R Upstream Transmission PSD Mask for ADSL2+ All Digital Mode

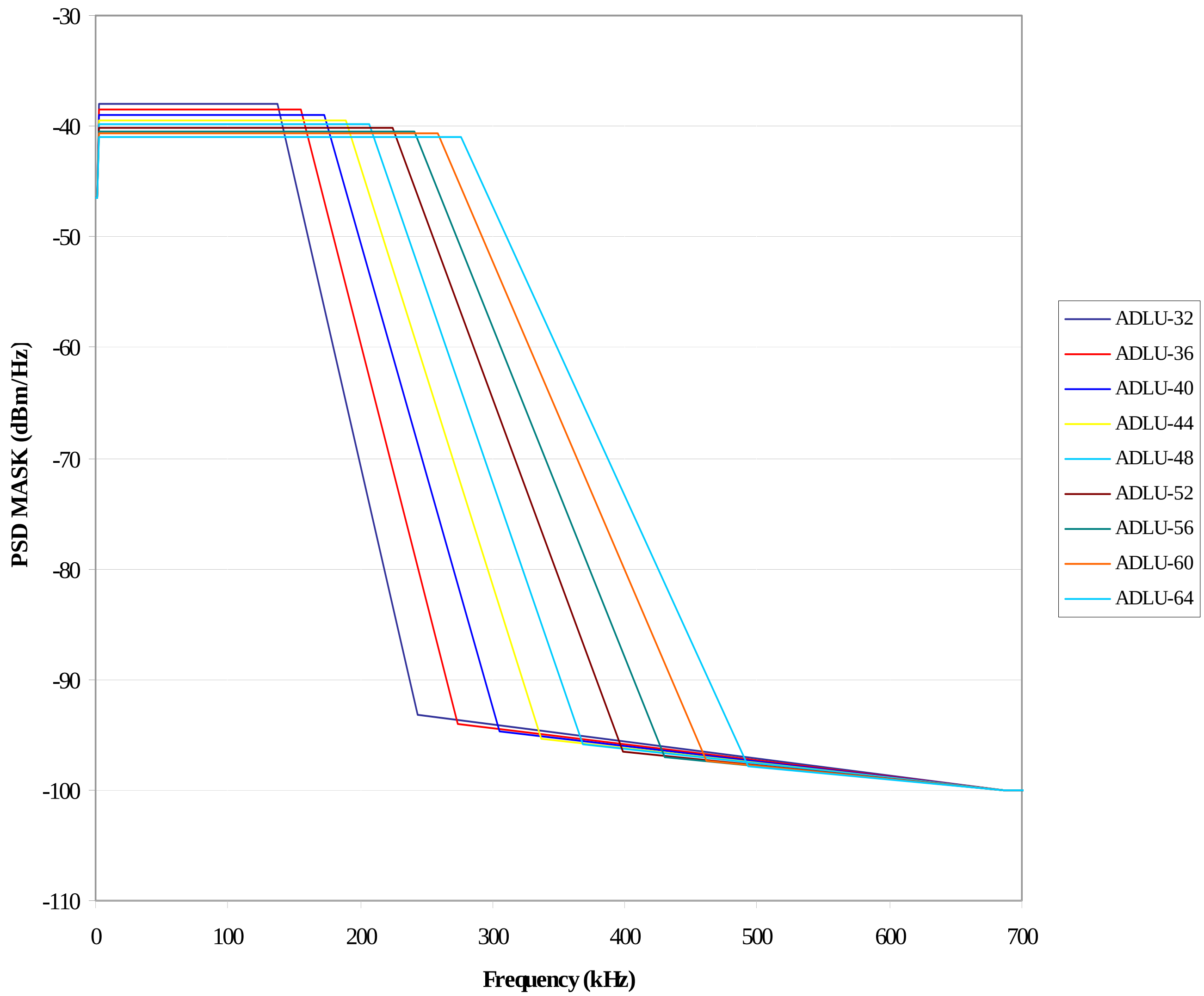


Figure 3.2.1.6(b): ATU-R Upstream Transmission PSD Mask Designator for ADSL2+ All Digital Mode

3.2.1.7 Power Spectral Density at the U-R Interface for ADSL2+ Extended Upstream

Table 3.2.1.7(a): ATU-R PSD Mask Definition ADSL2+ Extended Upstream

Frequency (kHz)	PSD (dBm/Hz)
0.2	-97.5
4	-97.5
4	-92.5
25.875	inband peak PSD
*f*1	inband peak PSD
*f*int	PSD int
686	-100
1411	-100 with a 1 MHz measurement bandwidth
1630	-100 with a 10 kHz measurement bandwidth and -110 with a 1 MHz measurement bandwidth
5275	-100 with a 10 kHz measurement bandwidth and -112 with a 1 MHz measurement bandwidth
30000	-100 with a 10 kHz measurement bandwidth and -112 with a 1 MHz measurement bandwidth

Note 1: The breakpoint frequencies and PSD values are exact.

Note 2: Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.

Note 3: The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.

Table 3.2.1.7(b): ATU-R Inband Peak PSD Mask Designator ADSL2+ Extended Upstream

Designator	Inband peak PSD (dBm/Hz)	Frequency *f*1 (kHz)	Frequency *f*int (kHz)	Intercept PSD (dBm/Hz)
EU - 32	-34.5	138	242.92	-93.2
EU - 36	-35	155.25	274	-94
EU - 40	-35.5	172.5	305.16	-94.7
EU - 44	-35.9	189.75	336.4	-95.4
EU - 48	-36.3	207	367.69	-95.9
EU - 52	-36.6	224.25	399.04	-96.5
EU - 56	-36.9	241.5	430.45	-97
EU - 60	-37.2	258.75	461.9	-97.4
EU - 64	-37.5	276	493.41	-97.9

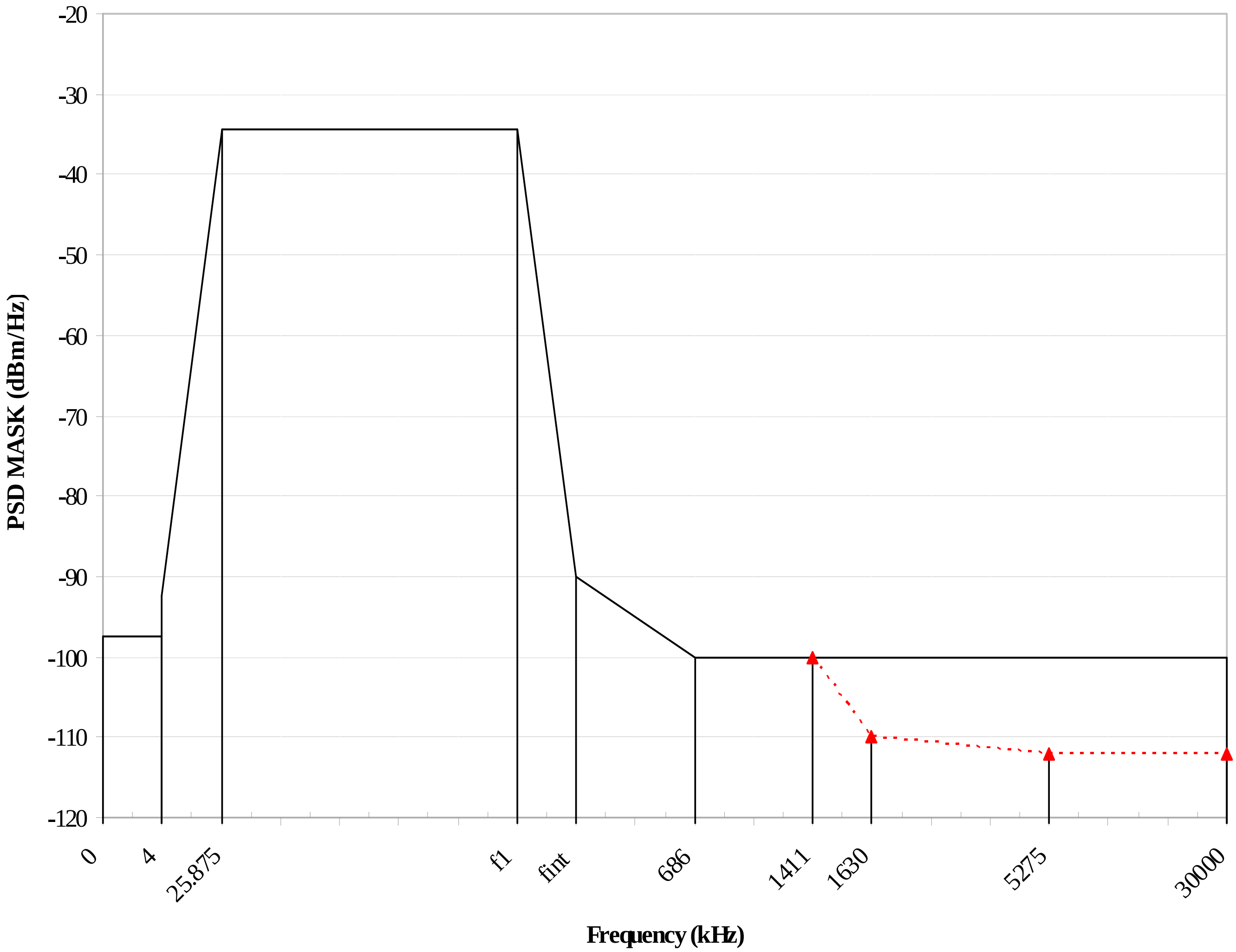


Figure 3.2.1.7(a): ATU-R Upstream Transmission PSD Mask for ADSL2+ Extended Upstream

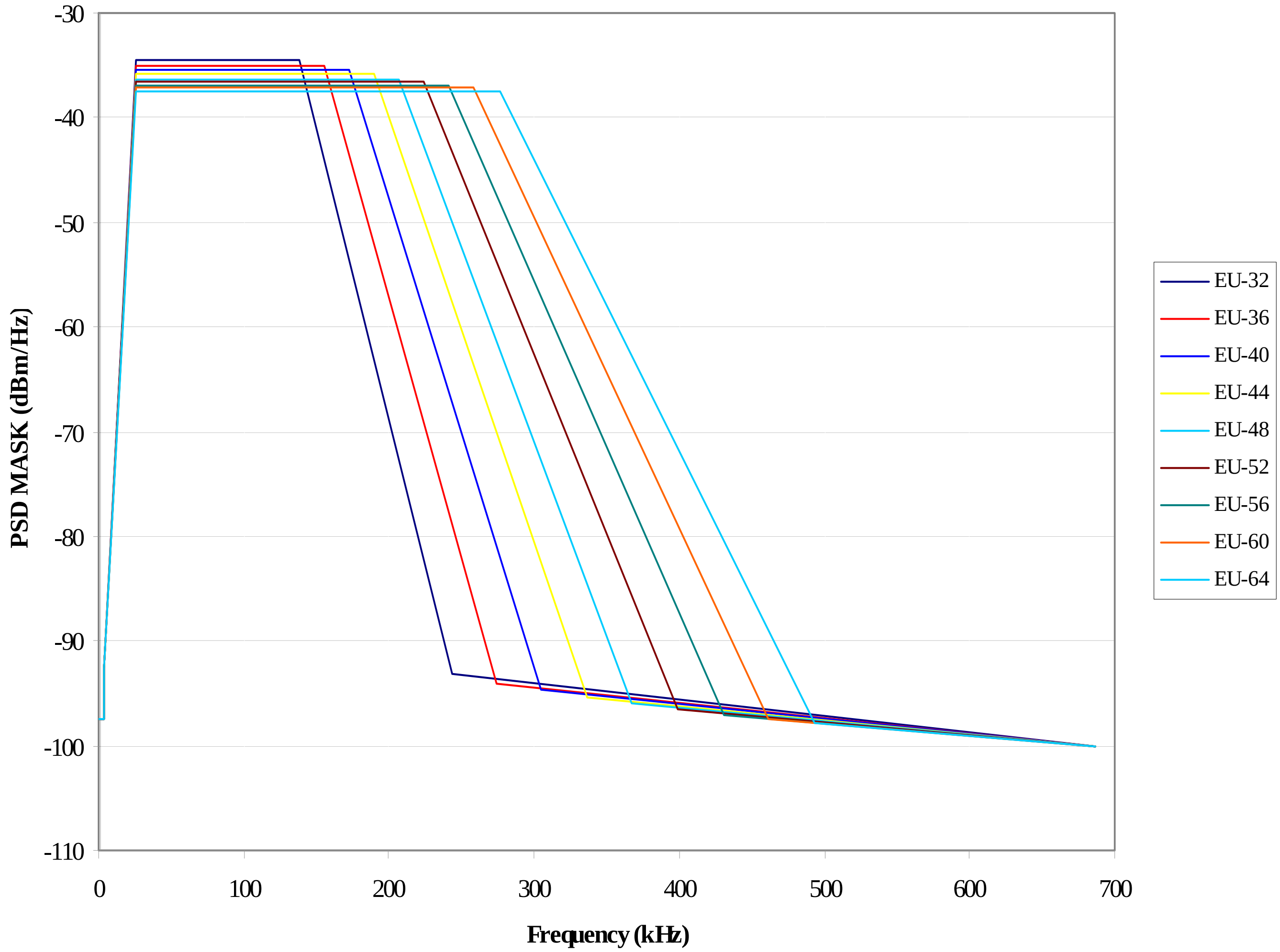


Figure 3.2.1.7(b): ATU-R Upstream Transmission PSD Mask Designator for ADSL2+ Extended Upstream

3.2.1.8 Power Spectral Density at the 2B1Q SDSL U-R Interface

The power spectral density of the signal transmitted by the 2B1Q SDSL transmitter shall follow the following equation:

$$SDSL_u(f) = \frac{2.7 \times 2.7}{135 \times f_{sym}} \left[\frac{\sin\left(\pi f / f_{sym} \right)}{\pi f / f_{sym}} \right]^2 \times \frac{1}{1 + \left(\frac{f}{\frac{240}{392} f_{sym}} \right)^8}$$

In this equation *f sym* is the symbol rate (which is equal to one-half of the line bit rate).

The actual 2B1Q PSD may differ from this template specification. However, for data rates below 1568 kbps, it shall comply with the PSD masks associated with each of the related data rates (see Table 3.2.1.8(a)). The PSD limits are defined by the equations and masks in the Tables 3.2.1.8(a), (b), (c), (d), (e), and (f), and Figures 3.2.1.8(a), (b), (c), (d), and (e).

The equipment shall not exceed the applicable PSD mask when operated at every data rate that the TE can achieve. The TE must be tested at least at the maximum data rate for each SDSL class that the TE is capable of operating in.

For data rates above 1568 kbps and up to 2320 kbps, the PSD of the transmitted signal shall not exceed the PSD limitations defined by the equation above (*SDSL u(f)*), increased by 3.5 dB. At frequencies above the point where the PSD mask, as define above, falls below the peak value of the next lobe, the maximum PSD shall be equal to that particular value until the peak PSD point of the next lobe is reached. At frequencies above the point where the PSD Mask, as defined above, falls below -90 dBm/Hz, the maximum PSD (out-of-band signal) shall not exceed -90 dBm/Hz up to 30 MHz.

Table 3.2.1.8(a): 2B1Q SDSL Data Rate and Associated PSD Mask Definition Tables and Figures

2B1Q SDSL Data Rate (kbps)	PSD Masks
Data Rate ≤ 288	Table 3.2.1.8(b) + Figure 3.2.1.8(a)
288 < Data Rate ≤ 528	Table 3.2.1.8(c) + Figure 3.2.1.8(b)
528 < Data Rate ≤ 784	Table 3.2.1.8(d) + Figure 3.2.1.8(c)
784 < Data Rate ≤ 1168	Table 3.2.1.8(e) + Figure 3.2.1.8(d)
1168 < Data Rate ≤ 1568	Table 3.2.1.8(f) + Figure 3.2.1.8(e)
1568 < Data Rate	See equation in section 3.2.1.8

Table 3.2.1.8(b): 2B1Q SDSL (Data Rate ≤ 288 kbps) PSD Mask Definition

Frequency Band (kHz)	PSD (dBm/Hz)
$0.2 < f \leq 25$	-29
$25 < f \leq 76$	$-29 - 10.35 \times \log_{10}(f/25)$
$76 < f \leq 79$	$-34 - 0.5 \times ((f-76)/3)$
$79 < f \leq 85$	$-34.5 - 19.6 \times \log_{10}((f-69)/10)$
$85 < f \leq 100$	$-38.5 - 4 \times ((f-85)/15)$
$100 < f \leq 115$	$-42.5 - 7 \times ((f-100)/15)$
$115 < f \leq 120$	-49.5
$120 < f \leq 225$	$-49.5 - 55 \times \log_{10}(f/120)$
$225 < f \leq 520$	$-64.5 - 70 \times \log_{10}(f/225)$
$520 < f \leq 30000$	-90

Table 3.2.1.8(c): 2B1Q SDSL (288 kbps < Data Rate ≤ 528 kbps) PSD Mask Definition

Frequency (kHz)	PSD (dBm/Hz)
0.2	-32.5
25	-32.5
75	-33
100	-35.5
150	-41.5
200	-50.5
230	-60.5
245	-67.5
335	-68.5
390	-72.5
440	-79.5
485 < *f* ≤ 30000	-90

Table 3.2.1.8(d): 2B1Q SDSL (528 kbps < Data Rate ≤ 784 kbps) PSD Mask Definition

Frequency (kHz)	PSD (dBm/Hz)
0.2	-33.5
50	-33.5
125	-34.5
210	-37.5
310	-53.5
370	-69.5
550	-71.5
670	-81.5
725 < *f* ≤ 30000	-90

Table 3.2.1.8(e): 2B1Q SDSL (784 kbps < Data Rate ≤ 1168 kbps) PSD Mask Definition

Frequency (kHz)	PSD (dBm/Hz)
0.2	-35.5
60	-35.5
200	-36.5
250	-37
315	-37.5
400	-49.5
500	-62.5
550	-71.5
750	-72.5
950	-80.5
1095 < *f* ≤ 30000	-90

Table 3.2.1.8(f): 2B1Q SDSL (1168 kbps < Data Rate ≤ 1568 kbps) PSD Mask Definition

Frequency (kHz)	PSD (dBm/Hz)
0.2	-36.5
100	-36.5
150	-37
200	-38
300	-38.5
390	-38.5
420	-39.5
500	-47.5
775	-73.5
1000	-73.5
1100	-76.5
1300	-82.5
1395 < *f* ≤ 30000	-90

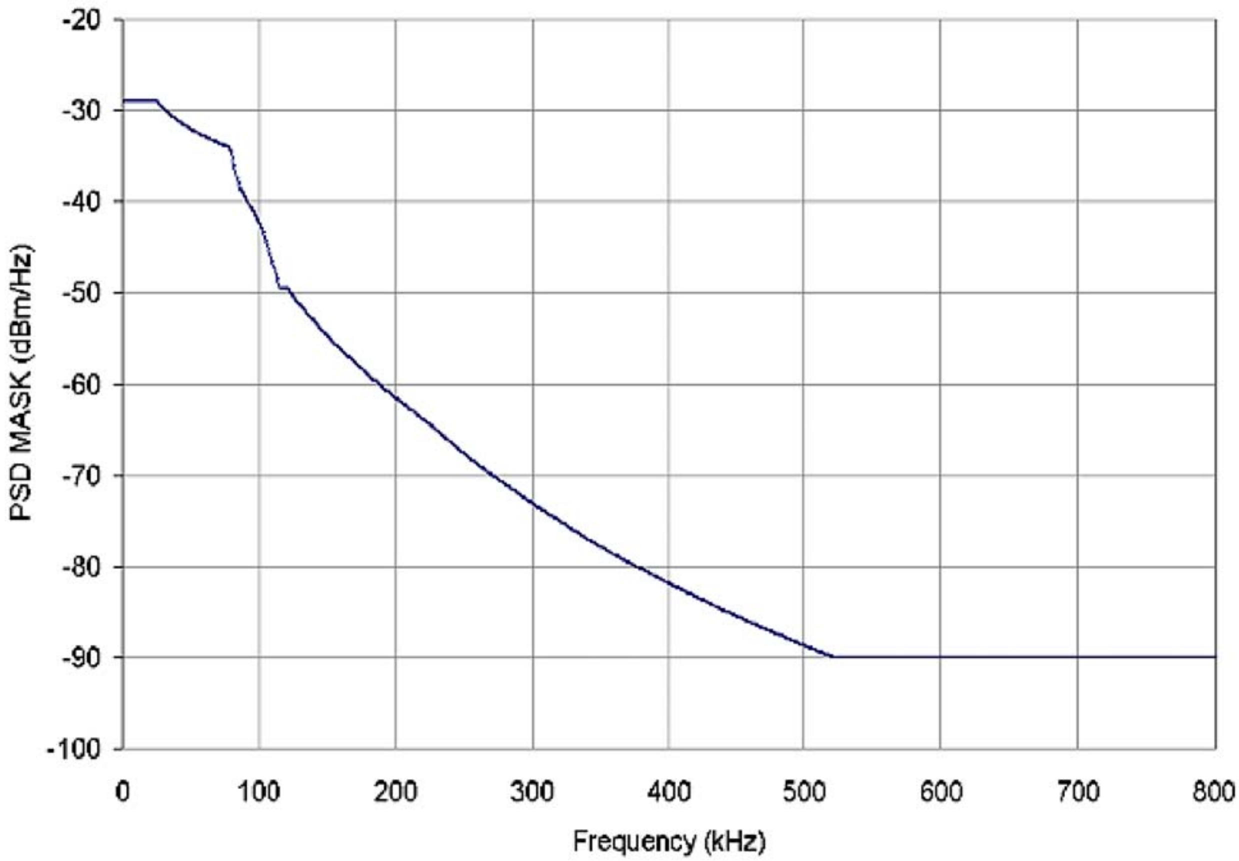


Figure 3.2.1.8(a): PSD Mask for 2B1Q SDSL (Data Rate ≤ 288 kbps)

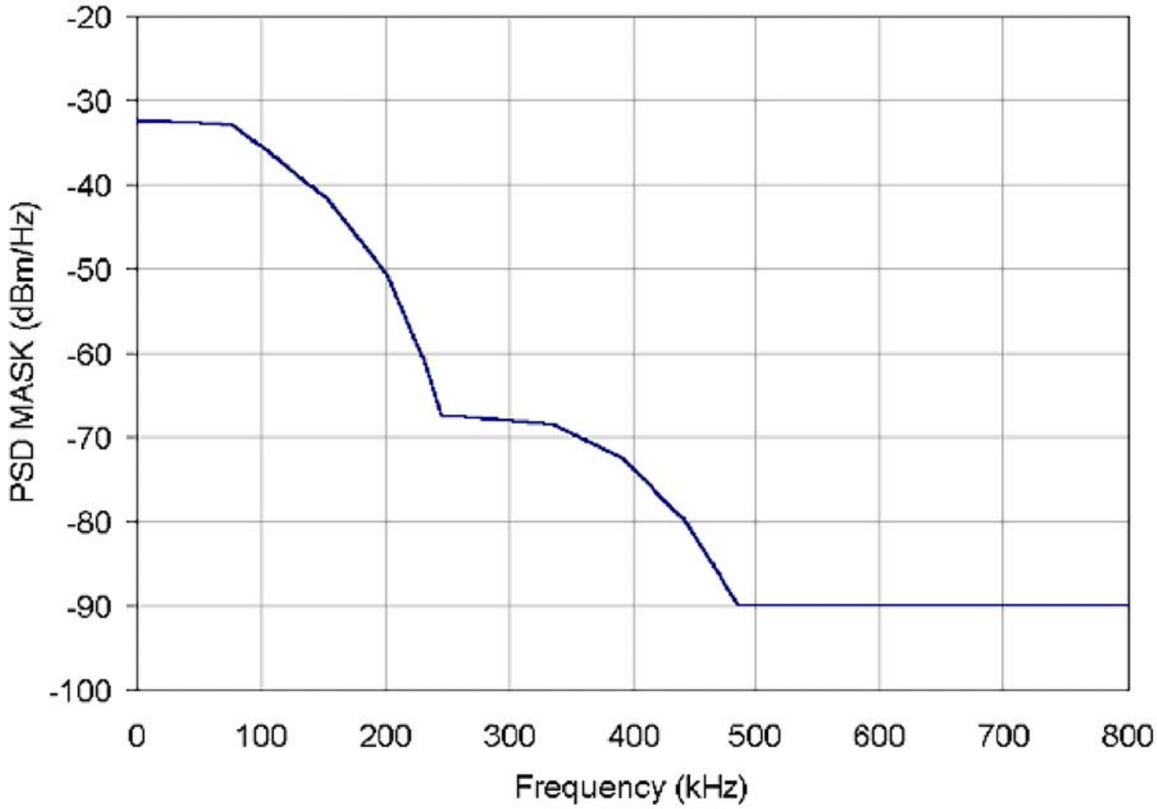


Figure 3.2.1.8(b): PSD Mask for 2B1Q SDSL (288 kbps < Data Rate ≤ 528 kbps)

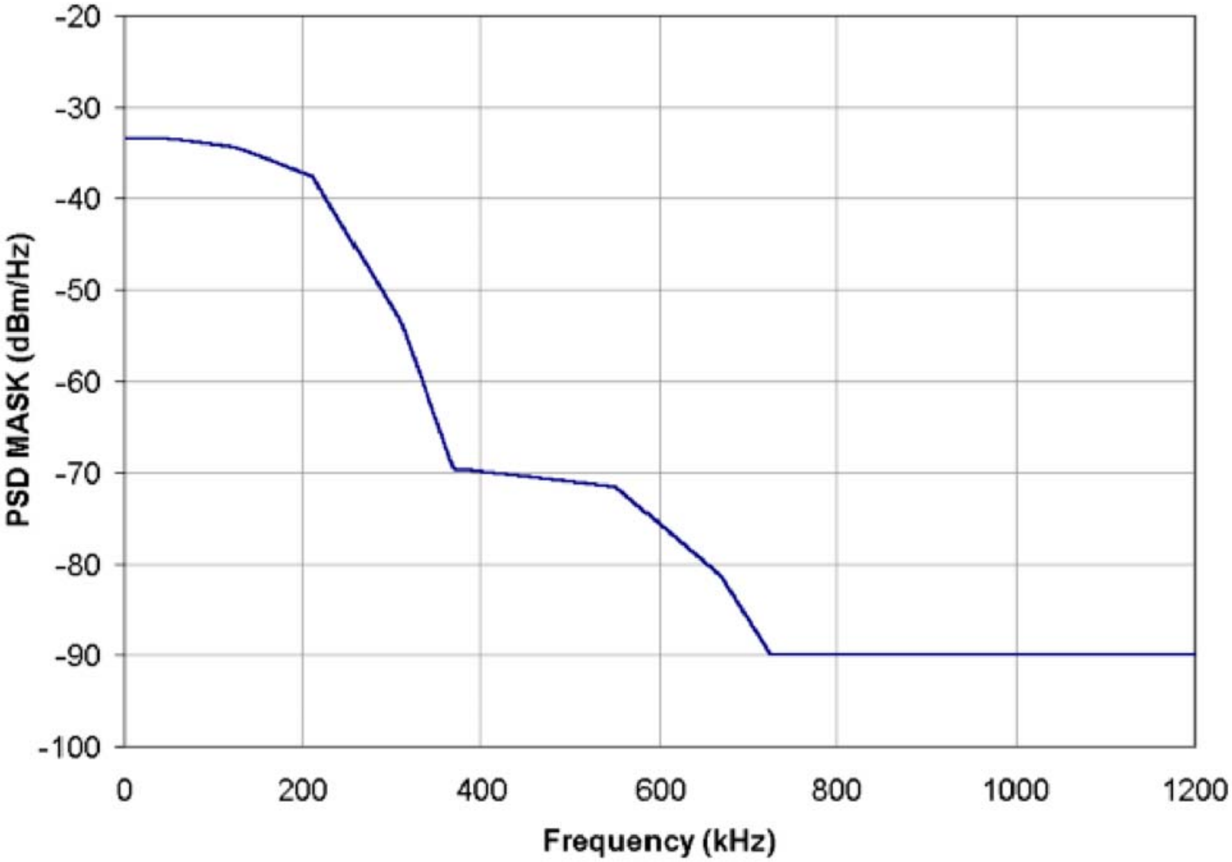


Figure 3.2.1.8(c): PSD Mask for 2B1Q SDSL (528 kbps < Data Rate ≤ 784 kbps)

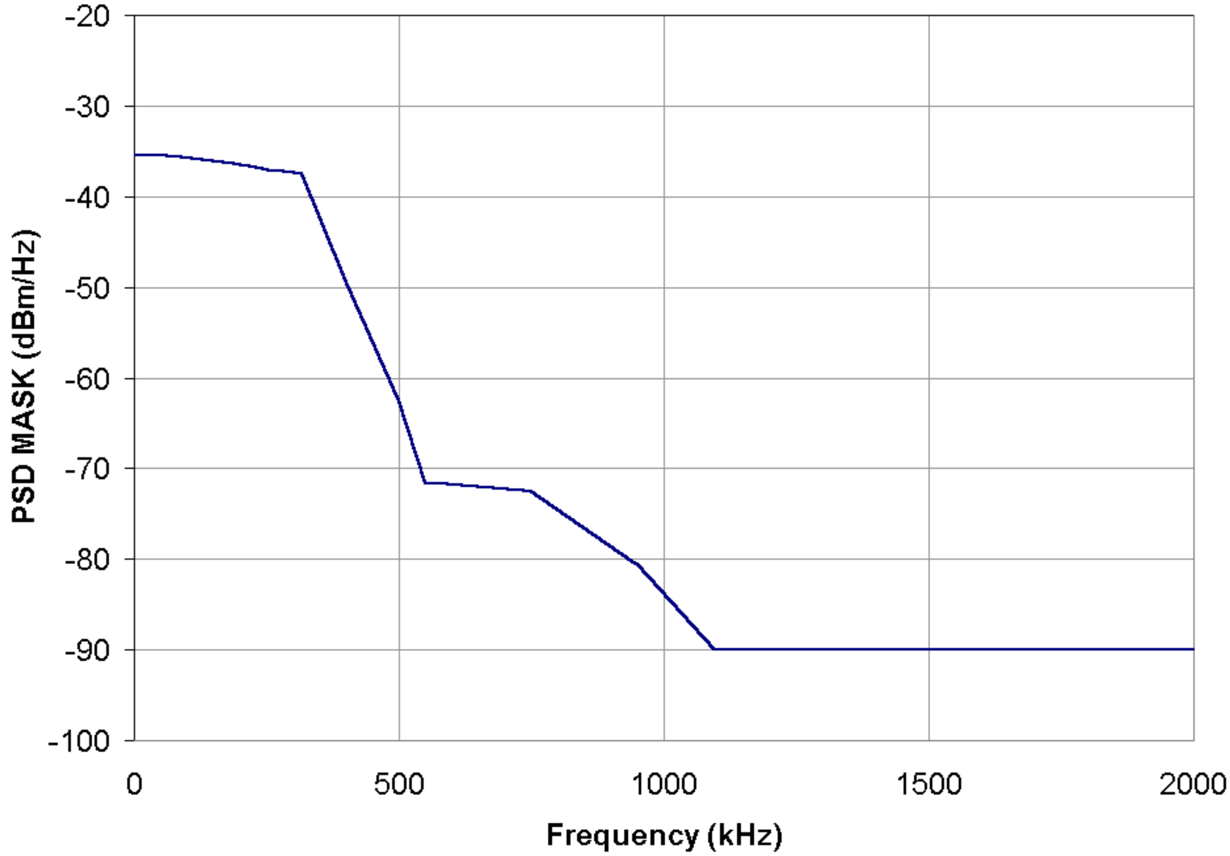


Figure 3.2.1.8(d): PSD Mask for 2B1Q SDSL (784 kbps < Data Rate ≤ 1168 kbps)

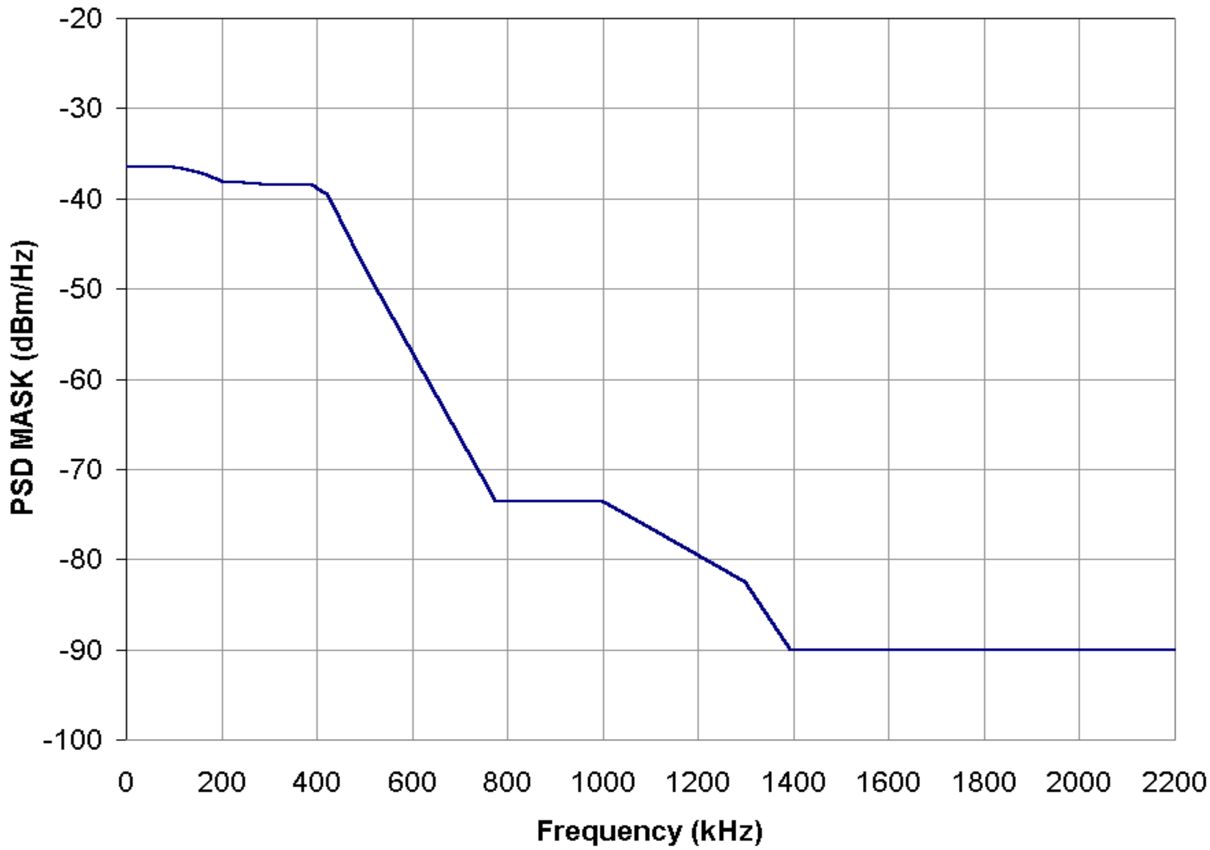


Figure 3.2.1.8(e): PSD Mask for 2B1Q SDSL (1168 kbps < Data Rate ≤ 1568 kbps)

3.2.1.9 Power Spectral Density at the HDSL (2B1Q) U-R Interface

The Power Spectral Density (PSD) of the HDSL (2B1Q) transmit signal measured at the U-R interface shall not exceed the PSD mask in Figure 3.2.1.9. Table 3.2.1.9 provides the numerical values for the mask.

Table 3.2.1.9: HDSL [2B1Q] PSD Mask Definition

Frequency (kHz)	PSD (dBm/Hz)
0.2	-33.5
50	-33.5
125	-34.5
210	-37.5
310	-53.5
370	-69.5
550	-71.5
670	-81.5
$725 < f \leq 30000$	-90

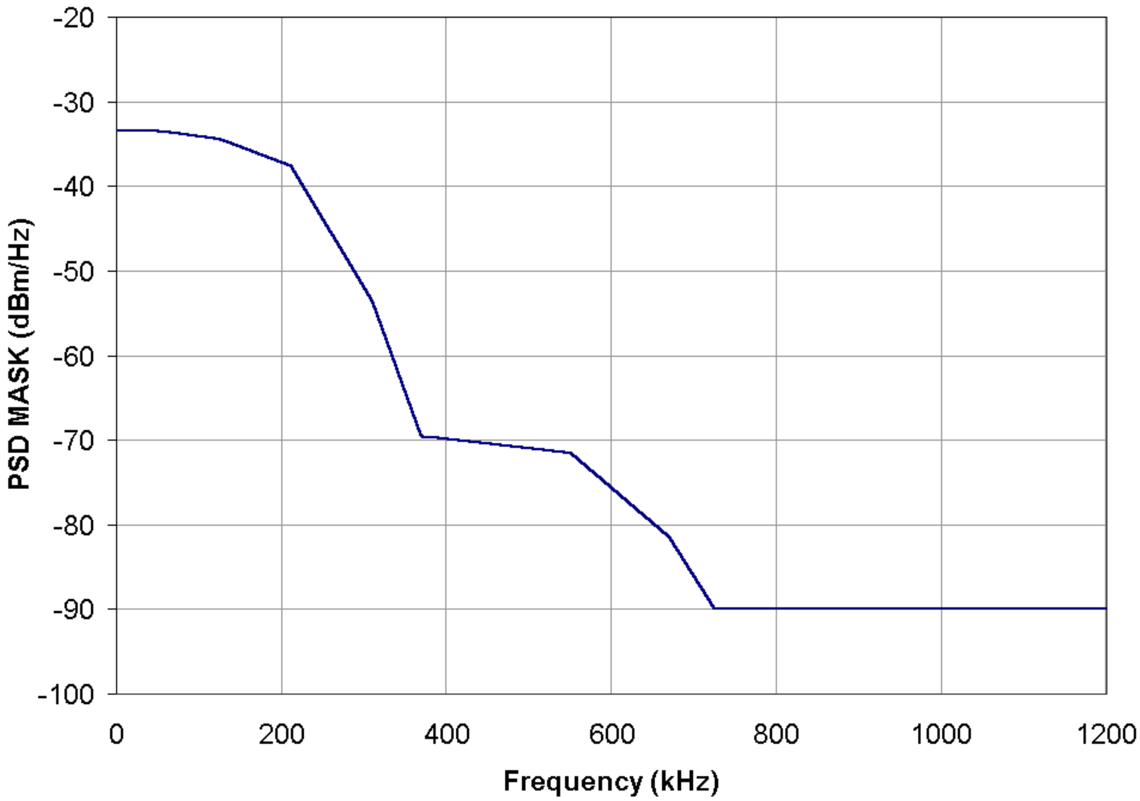


Figure 3.2.1.9: PSD Mask for HDSL [2B1Q] TU-R

3.2.1.10 Power Spectral Density at the HDSL (CAP) U-R Interface

The Power Spectral Density (PSD) of the HDSL (CAP) transmit signal measured at the U-R interface shall not exceed the PSD mask in Figure 3.2.1.10. Table 3.2.1.10 provides the numerical values for the mask.

Table 3.2.1.10: HDSL [CAP] TU-R PSD Mask Definition

Frequency (kHz)	PSD (dBm/Hz)
0.2	-36.5
100	-36.5
150	-37
200	-38
300	-38.5
390	-38.5
420	-39.5
500	-47.5
775	-73.5
1000	-73.5
1100	-76.5
1300	-82.5
$1395 < f \leq 30000$	-90

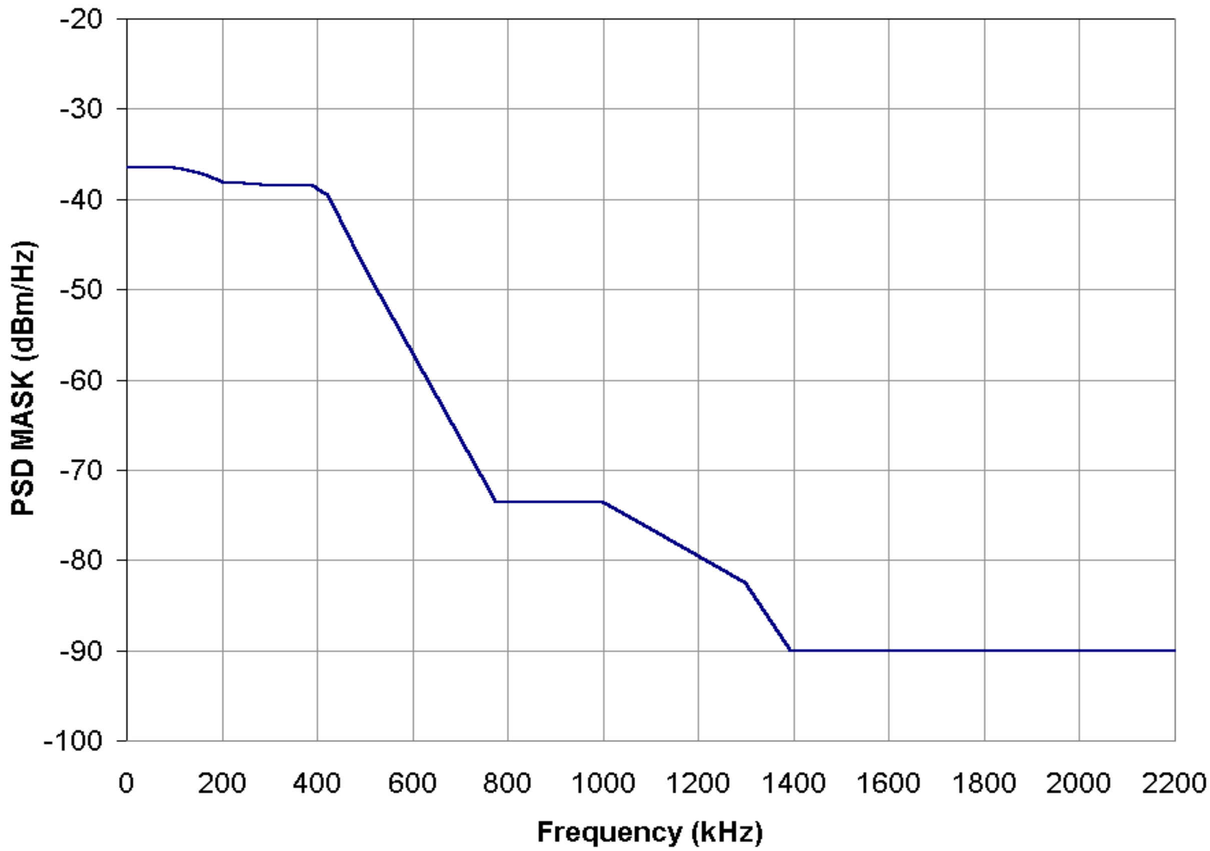


Figure 3.2.1.10: PSD Mask for HDSL [CAP] TU-R

3.2.1.11 Power Spectral Density at the HDSL2 U-R Interface

The power spectral density (PSD) of the HDSL2 transmit signal measured at the U-R interface shall not exceed the PSD mask defined in Table 3.2.1.11 and Figure 3.2.1.11.

Table 3.2.1.11: HDSL2 Mask Values for Spectral Shaper at the U-R Interface

Frequency (kHz)	PSD (dBm/Hz)	Frequency (kHz)	PSD (dBm/Hz)	Frequency (kHz)	PSD (dBm/Hz)
≤1	-54.2	220	-34.4	426	-90
2	-42.1	255	-34.4	30000	-90
10	-37.8	276	-41.1		
175	-37.8	300	-77.6		

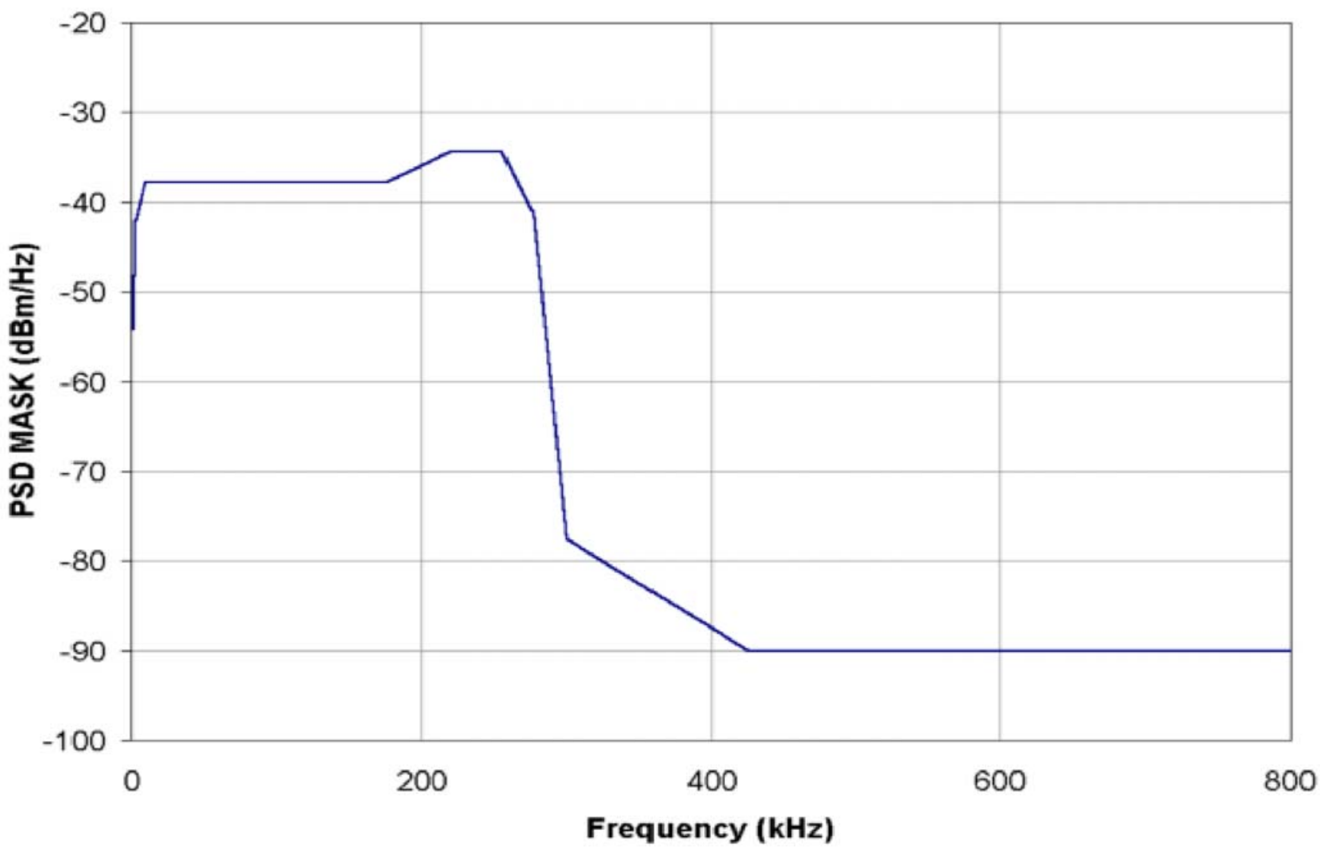


Figure 3.2.1.11: HDSL2 TU-R PSD Mask for the Upstream Transmission

3.2.1.12 Power Spectral Density at the SHDSL (Symmetric) U-R Interface

The power spectral density (PSD) of the signal transmitted by the SHDSL system shall not exceed the following PSD mask ($SHDSL_M(f)$):

$$SHDSL_M(f) = \begin{cases} \dfrac{K_{SHDSL}}{135} \times \dfrac{1}{f_{sym}} \times \dfrac{\left[\sin\left(\dfrac{\pi f}{f_{sym}}\right)\right]^2}{\left(\dfrac{\pi f}{f_{sym}}\right)^2} \times \dfrac{1}{1+\left(\dfrac{f}{f_{3dB}}\right)^{12}} \times 10^{\frac{MaskedOffsetdB(f)}{10}}, & f < f_{int} \\ 0.5683 \times 10^{-4} \times f^{-1.5}, & f_{int} \le f \le 1.1\ MHz \end{cases}$$

MaskOffsetdB(f) is defined as

$$MaskOffsetdB(f) = \begin{cases} 1 + 0.4 \times \dfrac{f_{3dB} - f}{f_{3dB}}, & f < f_{3dB} \\ 1, & f \ge f_{3dB} \end{cases}$$

f_{int} is the frequency where the two functions governing $SHDSL_M(f)$ intersect in the range 0 to f_{sym}. K_{SHDSL}, f_{sym}, f_{3dB} and the payload data rate *R* are defined in Table 3.2.1.12.

At frequencies above the point where the PSD mask, as define above, falls below the peak value of the next lobe, the maximum PSD shall be equal to that particular value until the peak PSD point of the next lobe is reached.

At frequencies above the point where the PSD mask as defined above falls below -90 dBm/Hz, the maximum PSD (out-of-band signal) shall not exceed -90 dBm/Hz up to 30 MHz.

The transmitted spectrum shall not exceed the applicable mask when the equipment is operated at any of the data rates specified in Annex A, Table 1(d). The TE must be tested at least at the maximum data rate for each designation shown in Annex A, Table 1(d), in which the TE is capable of operating.

Table 3.2.1.12: SHDSL Symmetric PSD Parameters

Line Bit Rate *LBR* (kbps)	K_{shdsl}	f_{sym} (ksymbols/s)	f_{3dB}
LBR ≠ 1544 or 1552	7.86	*LBR* / 3	1.0 x f_{sym} /2
LBR = 1544 or 1552	8.32	*LBR* / 3	0.9 x f_{sym} /2

3.2.1.13 Power Spectral Density at the Extended SHDSL U-R Interface

The power spectral density (PSD) of the signal transmitted by the EXTENDED SHDSL system shall not exceed the following PSD masks ($SHDSL_M(f)$):

$$SHDSL_M(f) = \begin{cases} \dfrac{K_{SHDSL}}{135} \times \dfrac{1}{f_{sym}} \times \dfrac{\left[\sin\left(\dfrac{\pi f}{N f_{sym}}\right)\right]^2}{\left(\dfrac{\pi f}{N f_{sym}}\right)^2} \times \dfrac{1}{1+\left(\dfrac{f}{f_{3dB}}\right)^{2\times Order}} \times 10^{\frac{MaskedOffsetdB(f)}{10}}\ W/Hz, & f < f_{int} \\ \text{-90 dBm/Hz peak, with max power in the } [f, f+1\text{ MHz}] \text{ window of} \\ [10\log_{10}(0.5683\times 10^{-4} \times f^{-1.5}) + 90]\text{dBm}, & f_{int} \le f \le 3.184MHz \\ \text{-90 peak dBm/Hz, with max power in the } [f, f+1\text{ MHz}] \text{ window of } -50dBm, & 3.184MHz \le f \le 12MHz \end{cases}$$

and the measured total power into 135 ohms shall not exceed +14 dBm.

MaskOffsetdB(f) is defined as

$$MaskOffsetdB(f) = \begin{cases} 1 + 0.4 \times \dfrac{f_{3dB} - f}{f_{3dB}} & , \quad f < f_{3dB} \\ 1 & , \quad f \geq f_{3dB} \end{cases}$$

f_{int} is the frequency where the two functions governing $SHDSL_M(f)$ intersect in the range 0 to f_{sym}. The variables K_{SHDSL}, *Order*, *N*, f_{sym}, and f_{3dB} are defined in Tables 3.2.1.13(a) and 3.2.1.13(b). *R* is the payload bit rate. The variables f, f_{sym}, f_{int} *and* f_{3dB} in the equations are in units of Hz.

Table 3.2.1.13(a): Symmetric PSD Parameters, 16-TCPAM

Payload Bit Rate, *R* (kbit/s)	K_{SHDSL}	Order	*N*	f_{sym} (ksymbol/s)	f_{3dB}
$2320 \leq R \leq 3840$	7.86	6	1	$(R+8)/3$	1.0 x $f_{sym}/2$

Table 3.2.1.13(b): Symmetric PSD Parameters, 32-TCPAM

Line Bit Rate, *R* (kbit/s)	K_{SHDSL}	Order	*N*	f_{sym} (ksymbol/s)	f_{3dB}
$768 \leq R \leq 5696$	7.86	6	1	$(R+8)/4$	1.0 x $f_{sym}/2$

3.2.1.14 Power Spectral Density at the HDSL4 U-R Interface

The power spectral density (PSD) of the HDSL4 transmit signal measured at the U-R interface shall not exceed the PSD mask defined in Table 3.2.1.14 and Figure 3.2.1.14.

Table 3.2.1.14: PSD Mask Definition for Upstream Transmission from HDSL4 TU-R

Frequency Band (kHz)	PSD (dBm/Hz)
$0 < f \leq 0.2$	-47.5
$0.2 < f \leq 2$	$-37.5 + 10(f-2)/1.8$
$2 < f \leq 5$	$-33.5 + 4(f-5)/3$
$5 < f \leq 50$	-33.5
$50 < f \leq 125$	$-33.5 - ((f-50)75)$
$125 < f \leq 130$	-34.5
$130 < f \leq 307$	$-34.5 - 142 \times \log_{10}(f/130)$
$307 < f \leq 30000$	-90

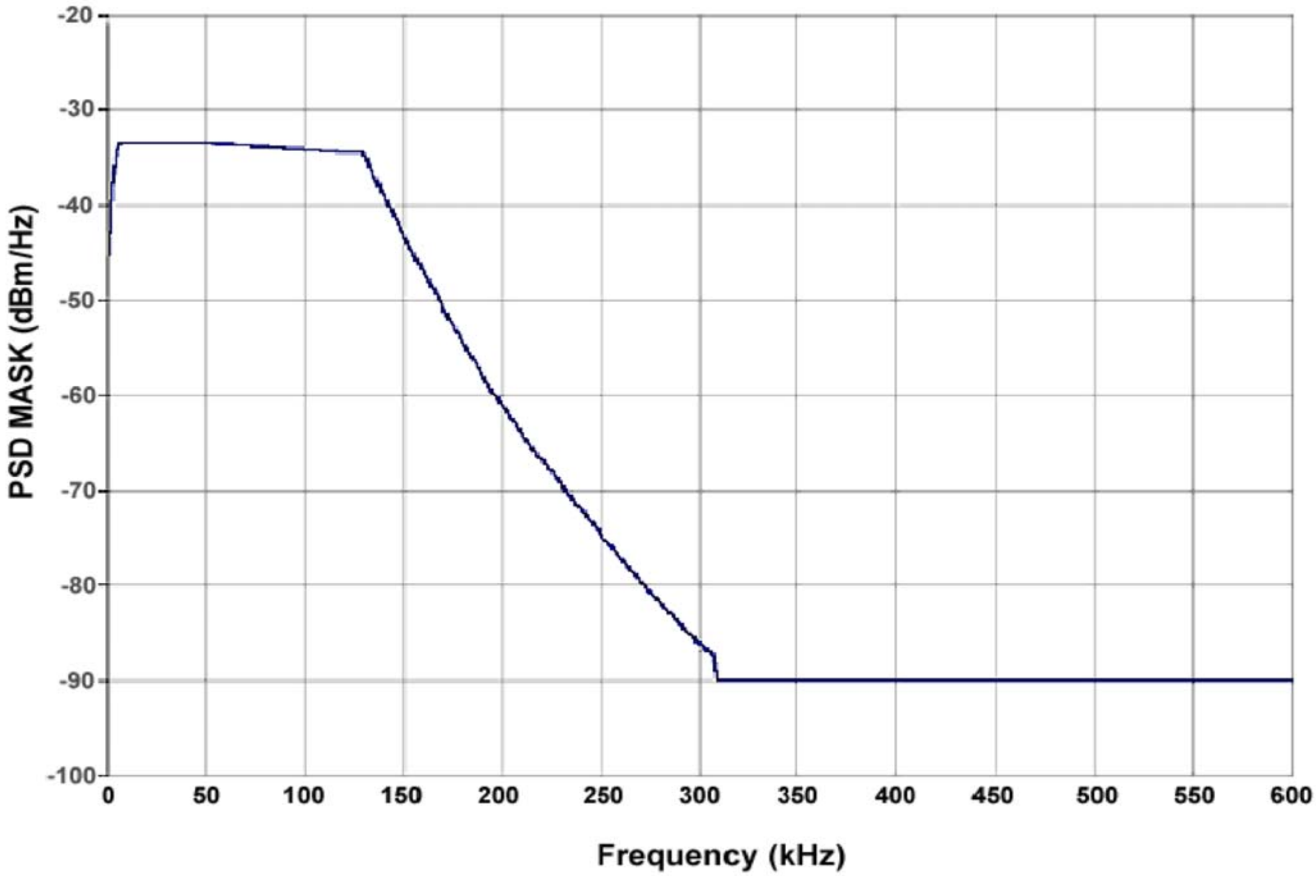


Figure 3.2.1.14: PSD Mask for Upstream Transmission from HDSL4 TU-R

3.2.1.15 Power Spectral Density at the U-R Interface for VDSL [QAM/DMT]

The Power Spectral Density (PSD) of the signal transmitted over the VDSL upstream channel (VTU-R output) shall not exceed the PSD mask in Figure 3.2.1.15 when operated at every data rate that the TE can achieve. The TE must be tested at least at the maximum data rate in which the TE is capable of operating. Table 3.2.1.15 provides the numerical values for the mask in Figure 3.2.1.15.

Table 3.2.1.15: VTU-R PSD Mask Definition (VDSL [QAM/DMT])

Frequency (kHz)	PSD (dBm/Hz)
0.2 - 4	-97.5
25	-34.5
138	-34.5
307	-86.5
368	-90
3655	-90
3750	-76.5
3751	-49.5
5199	-49.5
5200	-76.5
5287	-90
8412	-90
8500	-76.5
8501	-50.5
11999	-50.5
12000	-76.5
12087	-90
30000	-90

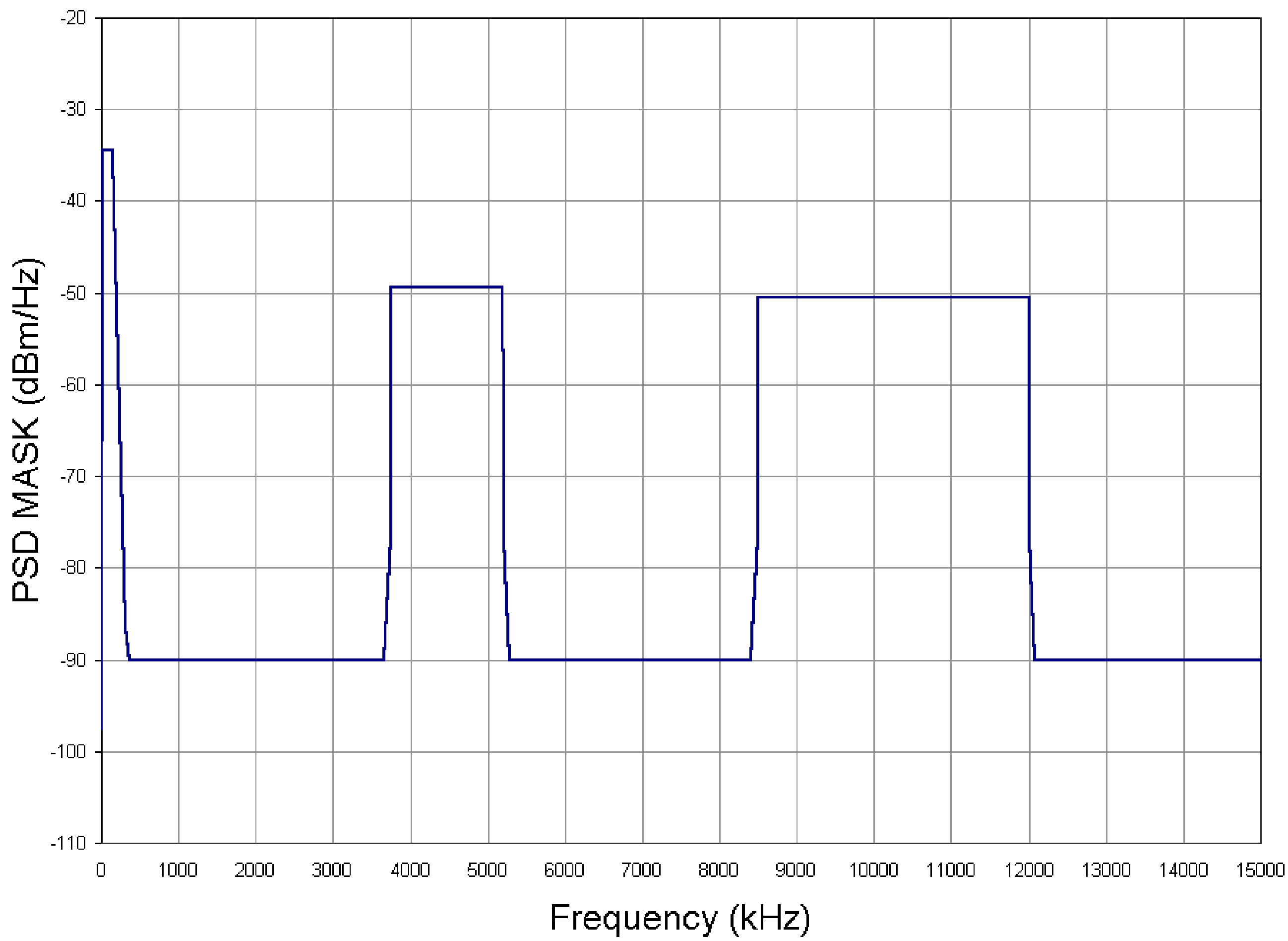


Figure 3.2.1.15: VTU-R Upstream Transmission PSD Mask for VDSL [QAM/DMT]

3.2.1.16 Power Spectral Density at the U-R Interface for VDSL2 over POTS

The Power Spectral Density (PSD) of the signal transmitted over the VDSL2 upstream channel (VTU-R output) shall not exceed the PSD masks in Figures 3.2.1.16(a) to (f) when operated at every data rate that the TE can achieve. The TE must be tested at least at the maximum data rate in which the TE is capable of operating. Tables 3.2.1.16 (a) and (b) provide the numerical values for the masks in Figures 3.2.1.16(a) to (f).

Table 3.2.1.16(a): VTU-R PSD Mask Definition (VDSL2 upstream operation over POTS

Frequency (kHz)	PSD level (dBm/Hz) for profiles 8a, 8b, 8c, 8d across 100 ohms	PSD level (dBm/Hz) for profiles 12a, 12b, 17a across 100 ohms	PSD level (dBm/Hz) for profiles 30a across 100 ohms	RBW
0.2	-97.5	-97.5	-97.5	100 Hz
4	-97.5	-97.5	-97.5	100 Hz
4	-92.5	-92.5	-92.5	100 Hz
25.875	*PSD1*	*PSD1*	*PSD1*	10 kHz
f_{OH}	*PSD1*	*PSD1*	*PSD1*	10 kHz
f_int	*PSD_int*	*PSD_int*	*PSD_int*	10 kHz
686	-100	-100	-100	10 kHz
3575	-100	-100	-100	10 kHz
3750	-80	-80	-80	10 kHz
3750	-49.5	-49.5	-49.5	10 kHz
5200	-49.5	-49.5	-49.5	10 kHz
5200	-80	-80	-80	10 kHz
5375	-100	-100	-100	10 kHz
8375	-100	-100	-100	10 kHz
8500	-100	-80	-80	10 kHz
8500	-100	-50.5	-50.5	10 kHz
12000	-100	-50.5	-50.5	10 kHz
12000	-100	-80	-80	10 kHz
12175	-100	-100	-100	10 kHz
22825	-100	-100	-100	10 kHz
23000	-100	-100	-80	10 kHz
23000	-100	-100	-56.5	10 kHz
30000	-100	-100	-56.5	10 kHz
30000	-	-	-80	10 kHz

Table 3.2.1.16(b): VTU-R Inband Peak *PSD1*, *PSDint* and the frequencies f_{OH} and f_{int} (VDSL2 upstream operation over POTS

Upstream Mask-Number	Designator	*PSD1* (dBm/Hz)	Frequency f_{OH} (kHz)	Intercept Frequency f_{int} (kHz)	Intercept PSD Level *PSDint* (dBm/Hz)
1	EU - 32	-34.5	138	242.92	-93.2
2	EU - 36	-35	155.25	274	-94
3	EU - 40	-35.5	172.5	305.16	-94.7
4	EU - 44	-35.9	189.75	336.4	-95.4
5	EU - 48	-36.3	207	367.69	-95.9
6	EU - 52	-36.6	224.25	399.04	-96.5
7	EU - 56	-36.9	241.5	430.45	-97
8	EU - 60	-37.2	258.75	461.9	-97.4
9	EU - 64	-37.5	276	493.41	-97.9

Note: EU-32 through EU-64 shall not be used in conjunction with EU-128

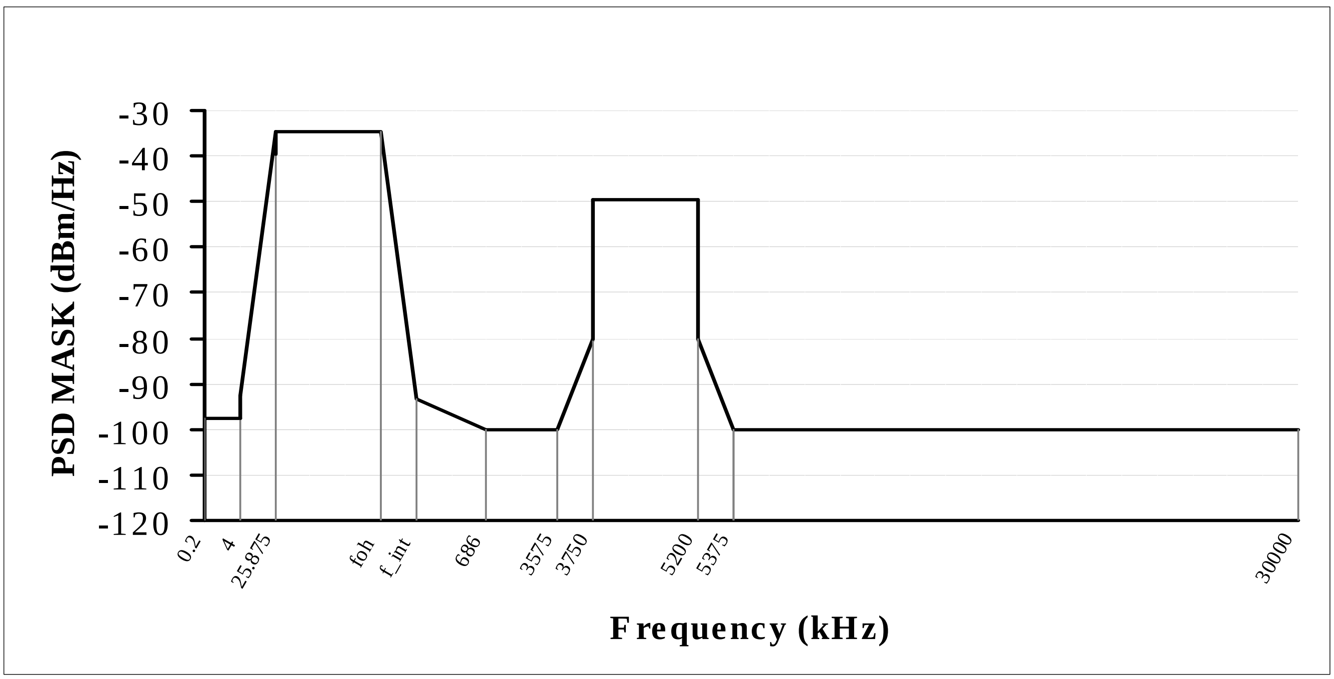


Figure 3.2.1.16(a): VDSL2 profiles 8a, 8b, 8c and 8d upstream operation over POTS PSD mask

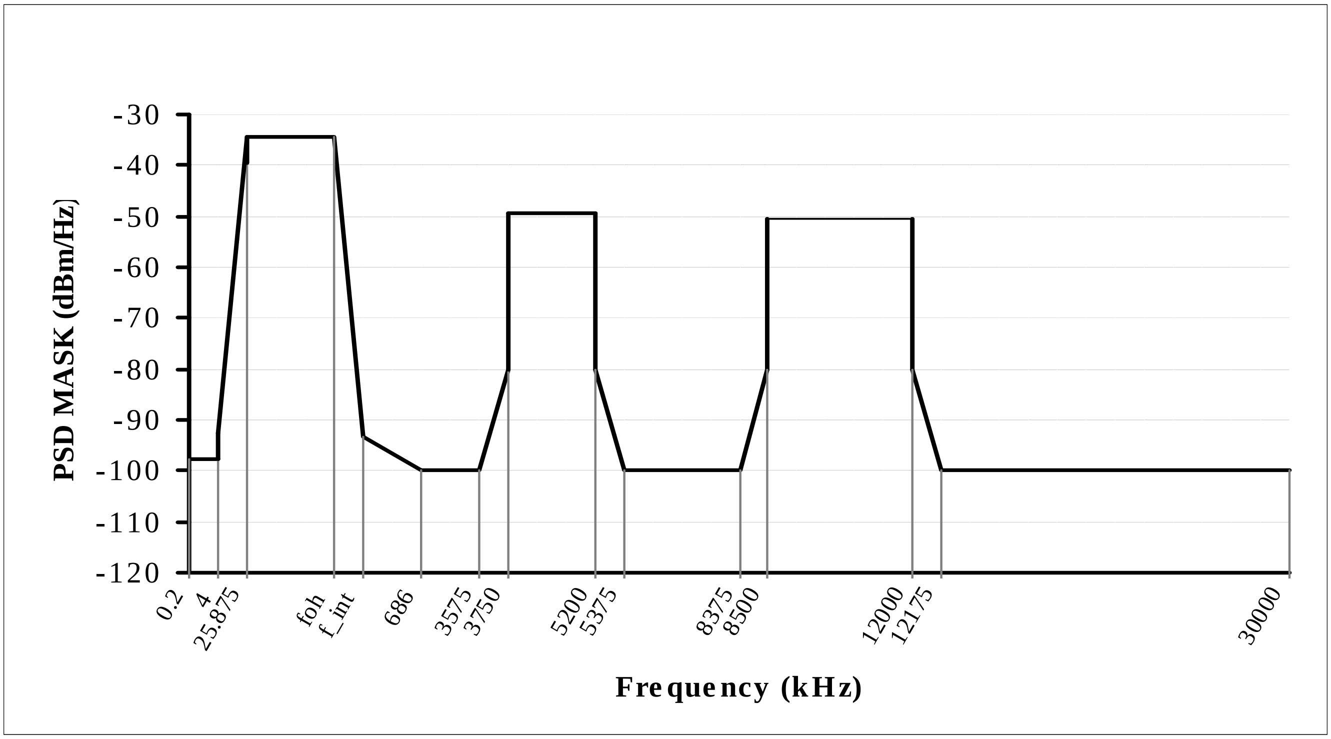


Figure 3.2.1.16(b): VDSL2 profiles 12a, 12b and 17a upstream operation over POTS PSD mask

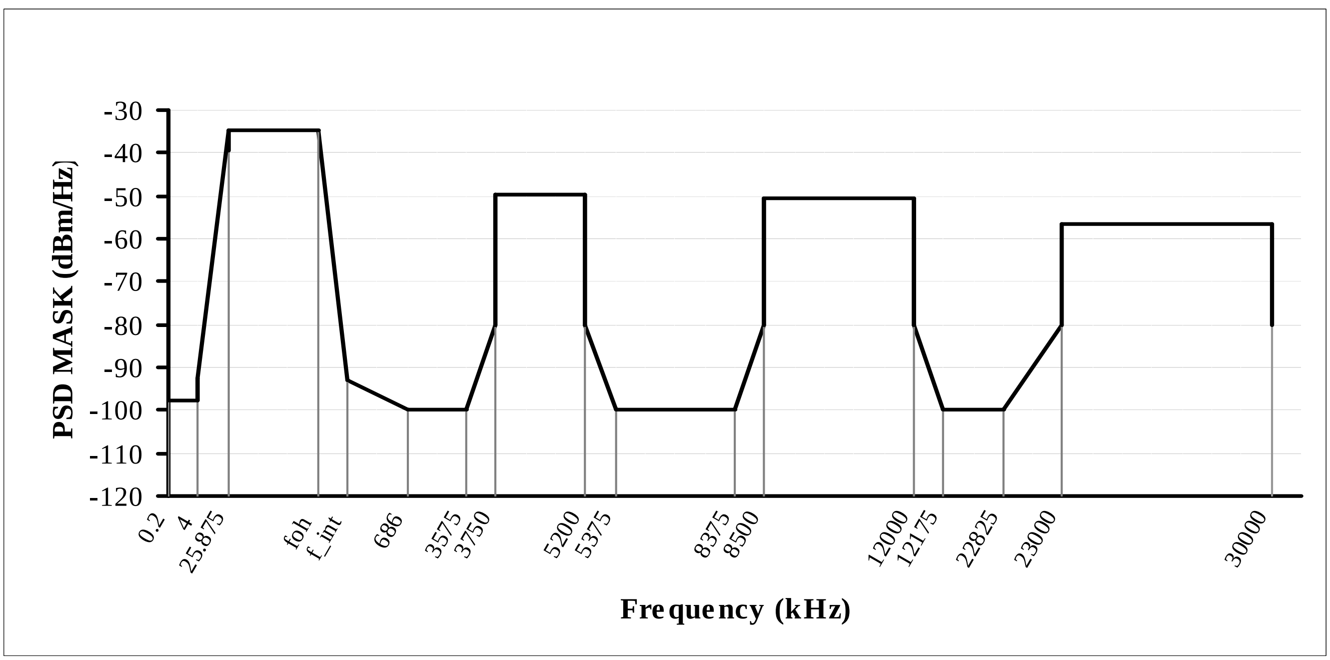


Figure 3.2.1.16(c): VDSL2 profile 30a upstream operation over POTS PSD mask

Table 3.2.1.16(c) – VDSL2 EU-128 profiles 8a, 8b, 8c, 8d, 12a, 12b, 17a and 30a upstream operation over POTS PSD mask limits

Frequency (kHz)	PSD level (dBm/Hz) for profiles 8a, 8b, 8c, 8d across 100 ohms	PSD level (dBm/Hz) for profiles 12a, 12b, 17a across 100 ohms	PSD level (dBm/Hz) for profiles 30a across 100 ohms	RBW
0.2	-97.5	-97.5	-97.5	100 Hz
4	-97.5	-97.5	-97.5	100 Hz
4	-92.5	-92.5	-92.5	100 Hz
25.875	-34.5	-34.5	-34.5	10 kHz
138	-34.5	-34.5	-34.5	10 kHz
552	-40.6	-40.6	-40.6	10 kHz
989	-100	-100	-100	10 kHz
3575	-100	-100	-100	10 kHz
3750	-80	-80	-80	10 kHz
3750	-49.5	-49.5	-49.5	10 kHz
5200	-49.5	-49.5	-49.5	10 kHz
5200	-80	-80	-80	10 kHz
5375	-100	-100	-100	10 kHz
8375	-100	-100	-100	10 kHz
8500	-100	-80	-80	10 kHz
8500	-100	-50.5	-50.5	10 kHz
12000	-100	-50.5	-50.5	10 kHz
12000	-100	-80	-80	10 kHz
12175	-100	-100	-100	10 kHz
22825	-100	-100	-100	10 kHz
23000	-100	-100	-80	10 kHz
23000	-100	-100	-56.5	10 kHz
30000	-100	-100	-56.5	10 kHz
30000	-	-	-80	10 kHz

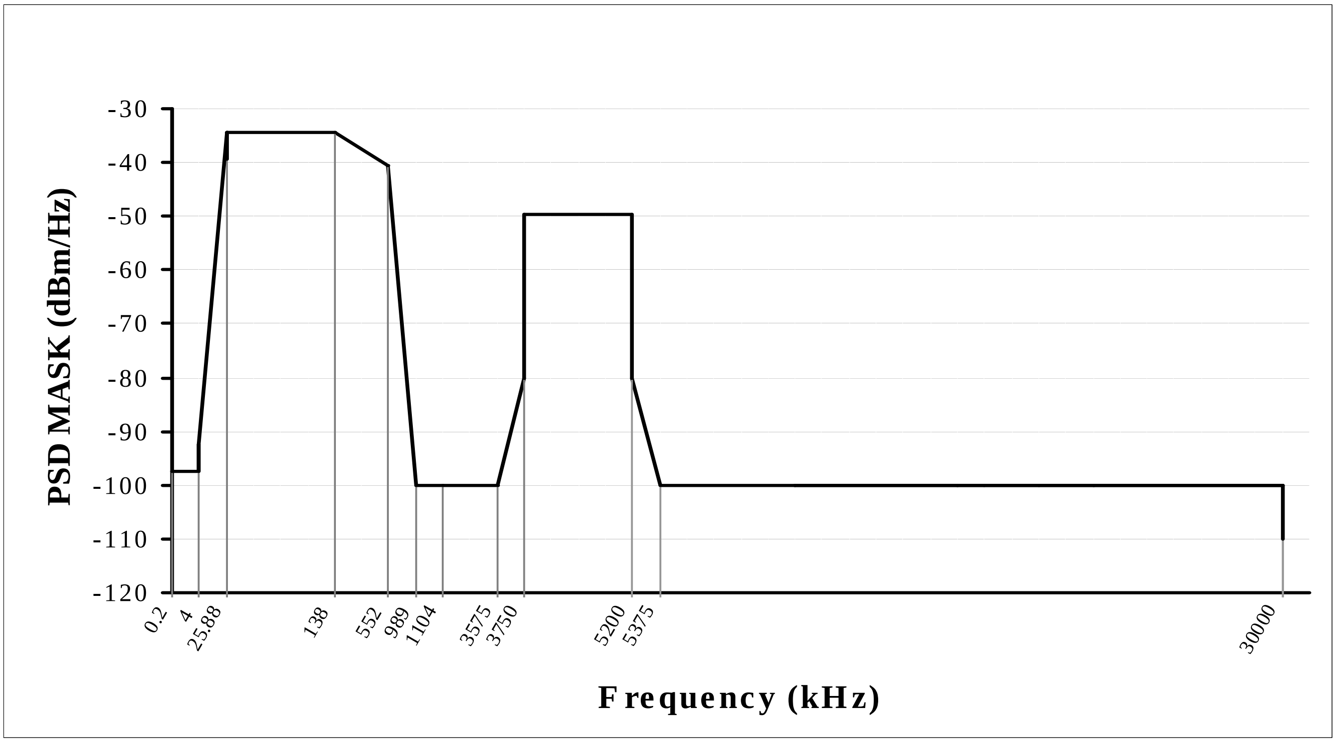


Figure 3.2.1.16(d): VDSL2 EU-128 profiles 8a, 8b, 8c and 8d upstream operation over POTS PSD mask

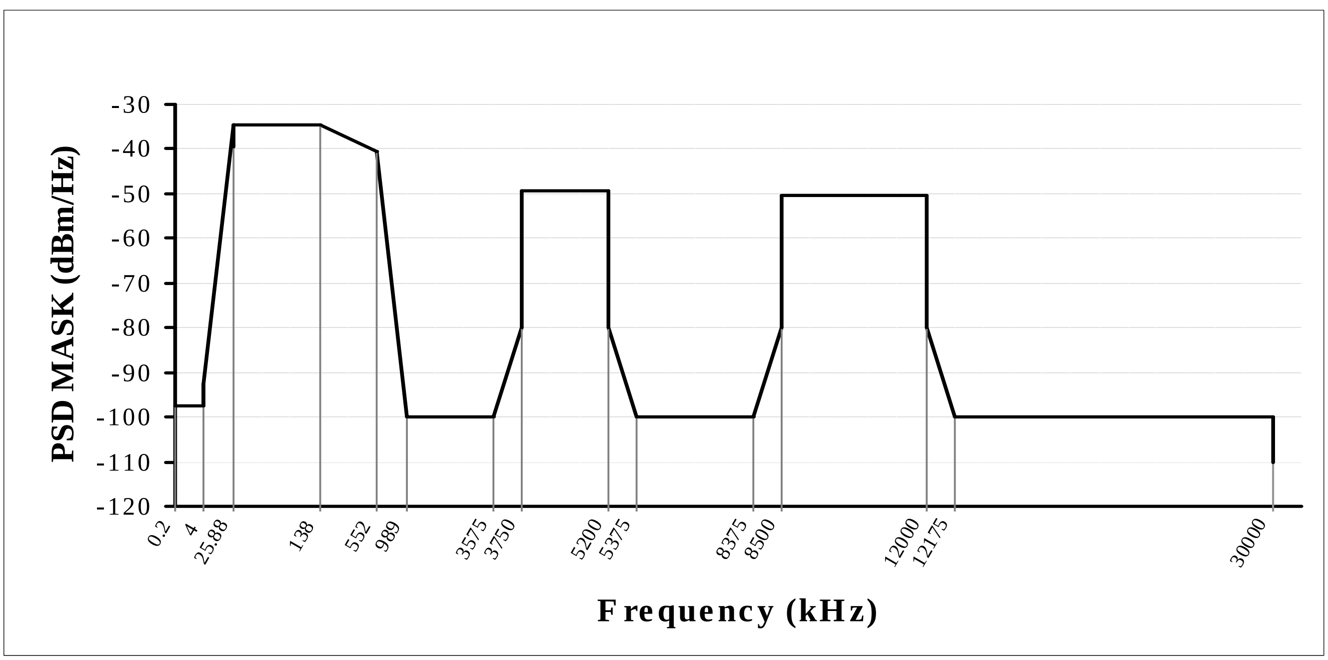


Figure 3.2.1.16(e): VDSL2 EU-128 profiles 12a, 12b and 17a upstream operation over POTS PSD mask

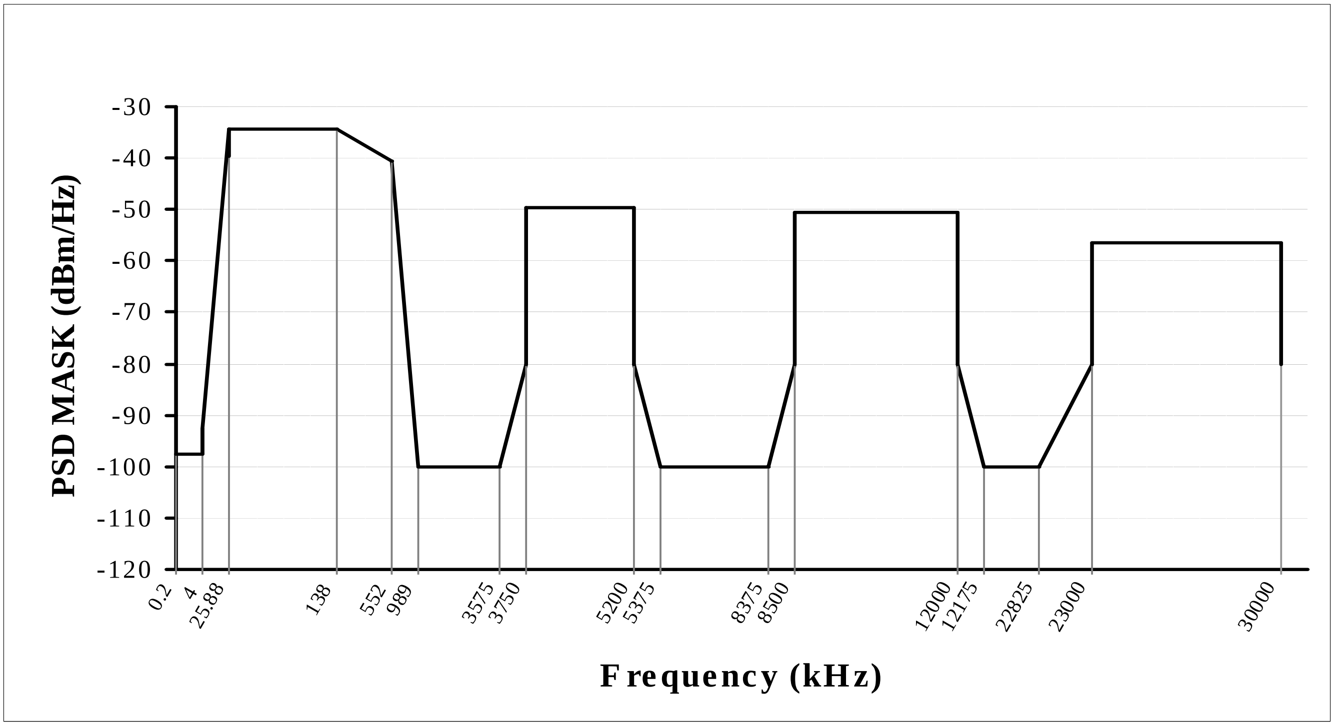


Figure 3.2.1.16(f): VDSL2 EU-128 profile 30a upstream operation over POTS PSD mask

3.2.1.17 Power Spectral Density at the U-R Interface for VDSL2 All Digital Mode

The Power Spectral Density (PSD) of the signal transmitted over the VDSL2 upstream channel (VTU-R output) shall not exceed the PSD masks in Figures 3.2.1.17(a) to (f) when operated at every data rate that the TE can achieve. The TE must be tested at least at the maximum data rate in which the TE is capable of operating. Tables 3.2.1.17 (a) and (b) provide the numerical values for the masks in Figures 3.2.1.17(a) to (f).

Table 3.2.1.17(a): VTU-R PSD Mask Definition (VDSL2 upstream operation All Digital Mode)

Frequency (kHz)	PSD level (dBm/Hz) for profile 8a, 8b, 8c, 8d across 100 ohms	PSD level (dBm/Hz) for profiles 12a, 12b, 17a across 100 ohms	PSD level (dBm/Hz) for profiles 30a across 100 ohms	RBW
0.2	-46.5	-46.5	-46.5	100 Hz
1.5	-46.5	-46.5	-46.5	100 Hz
3	*PSD1*	*PSD1*	*PSD1*	100 Hz
f_{OH}	*PSD1*	*PSD1*	*PSD1*	10 kHz
f_int	*PSD_int*	*PSD_int*	*PSD_int*	10 kHz
686	-100	-100	-100	10 kHz
3575	-100	-100	-100	10 kHz
3750	-80	-80	-80	10 kHz
3750	-49.5	-49.5	-49.5	10 kHz
5200	-49.5	-49.5	-49.5	10 kHz
5200	-80	-80	-80	10 kHz
5375	-100	-100	-100	10 kHz
8375	-100	-100	-100	10 kHz
8500	-100	-80	-80	10 kHz
8500	-100	-50.5	-50.5	10 kHz
12000	-100	-50.5	-50.5	10 kHz
12000	-100	-80	-80	10 kHz
12175	-100	-100	-100	10 kHz
22825	-100	-100	-100	10 kHz
23000	-100	-100	-80	10 kHz
23000	-100	-100	-56.5	10 kHz
30000	-100	-100	-56.5	10 kHz
30000	-	-	-80	10 kHz

Table 3.2.1.17(b): VTU-R Inband Peak *PSD1*, *PSDint* and the frequencies f_{OH} and f_{int} (VDSL2 upstream operation All Digital Mode)

Upstream Mask-Number	Designator	*PSD1* (dBm/Hz)	Frequency f_{OH} (kHz)	Intercept Frequency f_{int} (kHz)	Intercept PSD Level *PSDint* (dBm/Hz)
1	ADLU - 32	-34.5	138	242.92	-93.2
2	ADLU - 36	-35	155.25	274	-94
3	ADLU - 40	-35.5	172.5	305.16	-94.7
4	ADLU - 44	-35.9	189.75	336.4	-95.4
5	ADLU - 48	-36.3	207	367.69	-95.9
6	ADLU - 52	-36.6	224.25	399.04	-96.5
7	ADLU - 56	-36.9	241.5	430.45	-97
8	ADLU - 60	-37.2	258.75	461.9	-97.4
9	ADLU - 64	-37.5	276	493.41	-97.9

Note: EU-32 through EU-64 shall not be used in conjunction with EU

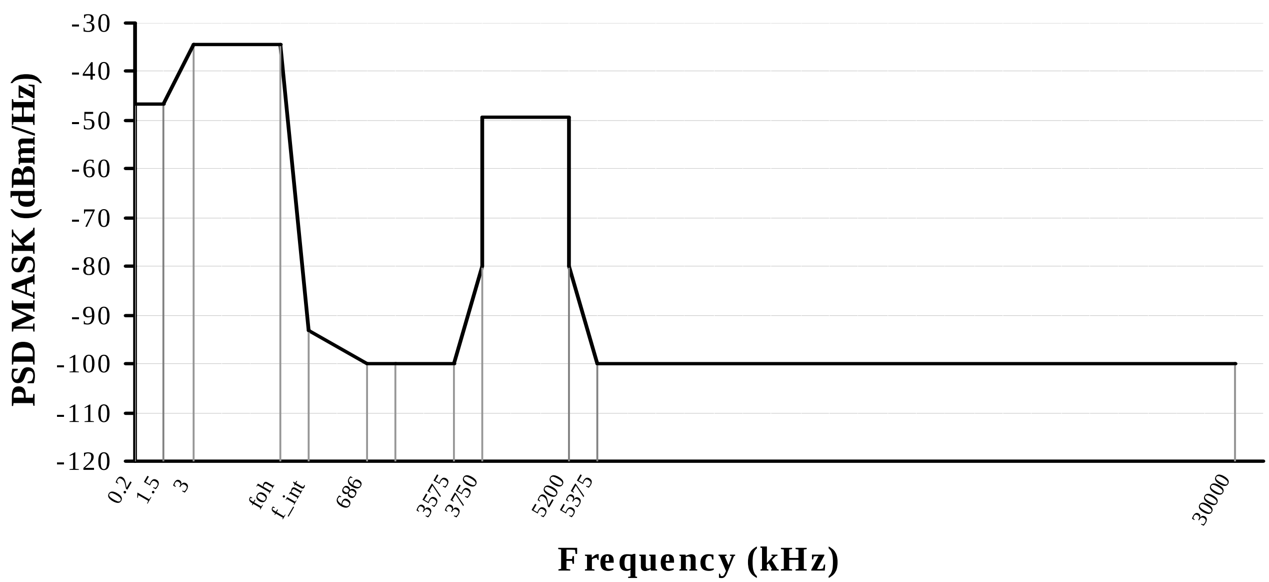


Figure 3.2.1.17(a): VDSL2 profiles 8a, 8b, 8c and 8d upstream all digital mode operation PSD mask

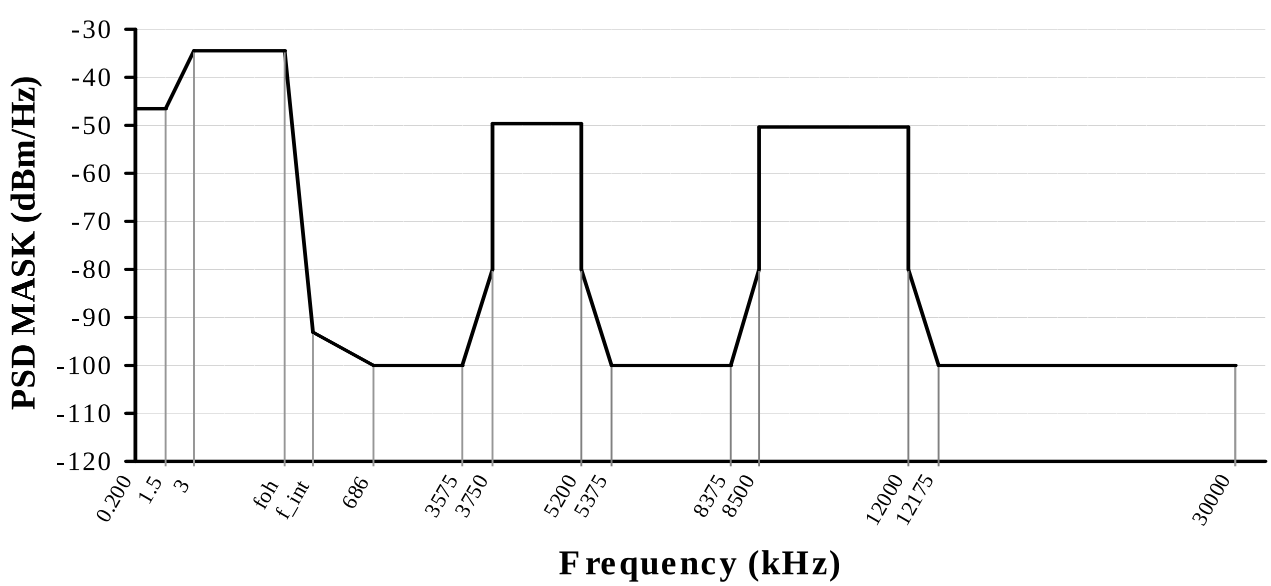


Figure 3.2.1.17(b): VDSL2 profiles 12a, 12b and 17a upstream all digital mode operation PSD mask

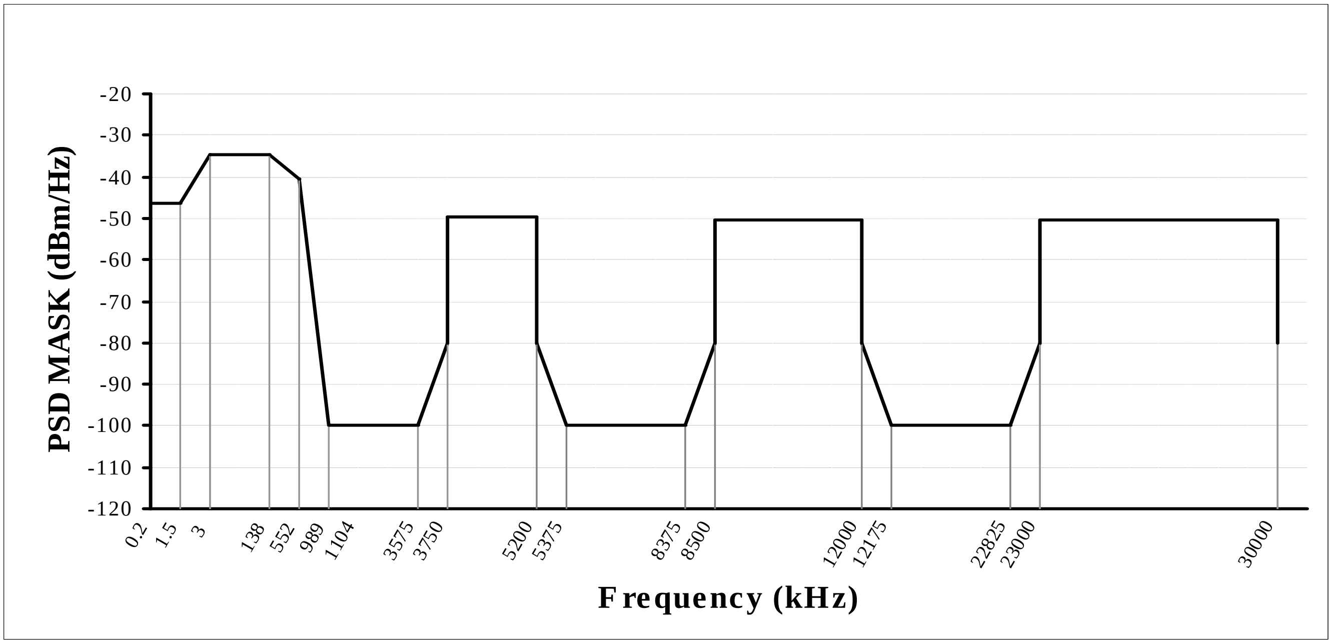


Figure 3.2.1.17(c): VDSL2 profile 30a upstream all digital mode operation PSD mask

Table 3.2.1.17(c): VDSL2 ADLU-128 profiles 8a, 8b, 8c, 8d, 12a, 12b, 17a and 30a upstream all digital mode operation mask limits

Frequency (kHz)	PSD level (dBm/Hz) for profiles 8a, 8b, 8c, 8d across 100 ohms	PSD level (dBm/Hz) for profiles 12a, 12b, 17a across 100 ohms	PSD level (dBm/Hz) for profiles 30a across 100 ohms	RBW
0.2	-46.5	-46.5	-46.5	100 Hz
1.5	-46.5	-46.5	-46.5	100 Hz
3	-34.5	-34.5	-34.5	100 Hz
138	-34.5	-34.5	-34.5	10 kHz
552	-40.6	-40.6	-40.6	10 kHz
989	-100	-100	-100	10 kHz
3575	-100	-100	-100	10 kHz
3750	-80	-80	-80	10 kHz
3750	-49.5	-49.5	-49.5	10 kHz
5200	-49.5	-49.5	-49.5	10 kHz
5200	-80	-80	-80	10 kHz
5375	-100	-100	-100	10 kHz
8375	-100	-100	-100	10 kHz
8500	-100	-80	-80	10 kHz
8500	-100	-50.5	-50.5	10 kHz
12000	-100	-50.5	-50.5	10 kHz
12000	-100	-80	-80	10 kHz
12175	-100	-100	-100	10 kHz
22825	-100	-100	-100	10 kHz
23000	-100	-100	-80	10 kHz
23000	-100	-100	-56.5	10 kHz
30000	-100	-100	-56.5	10 kHz
30000	-	-	-80	10 kHz

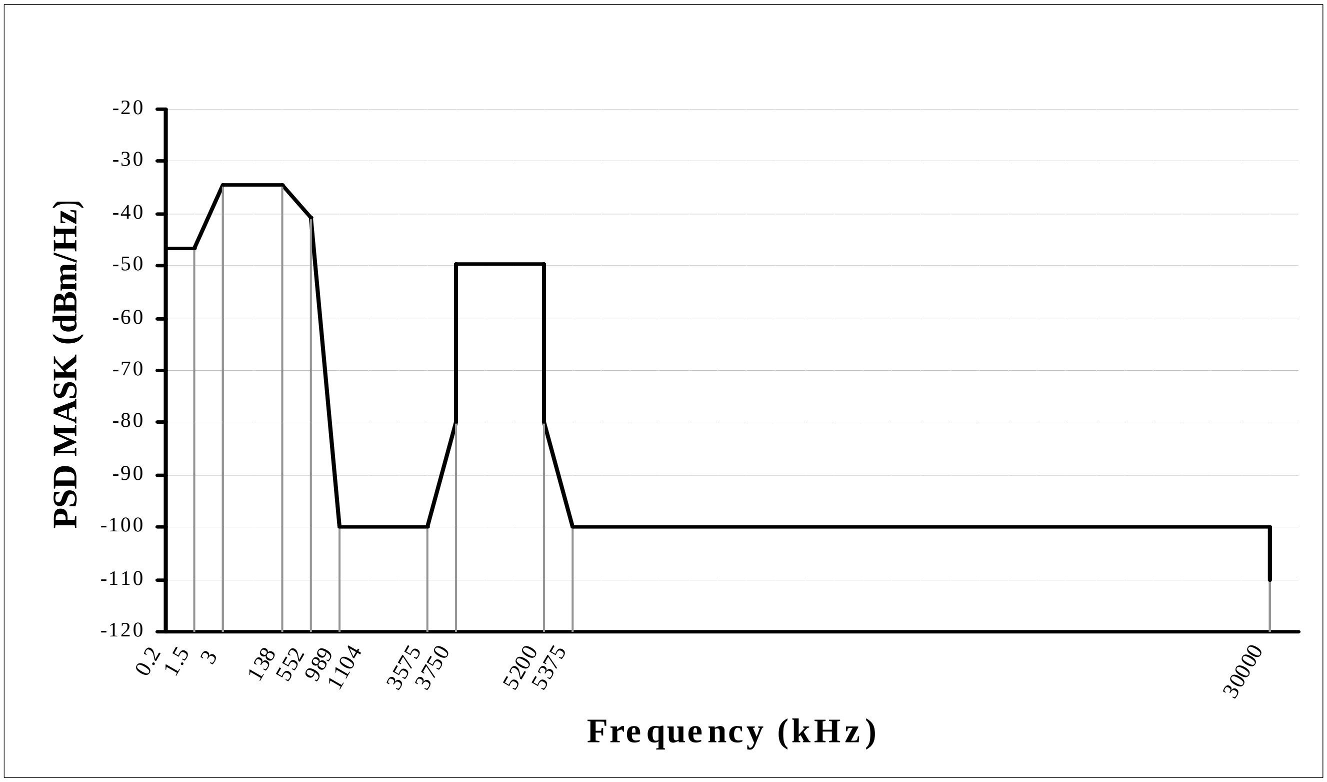


Figure 3.2.1.17(d): VDSL2 ADLU-128 profiles 8a, 8b, 8c and 8d upstream all digital mode operation PSD mask

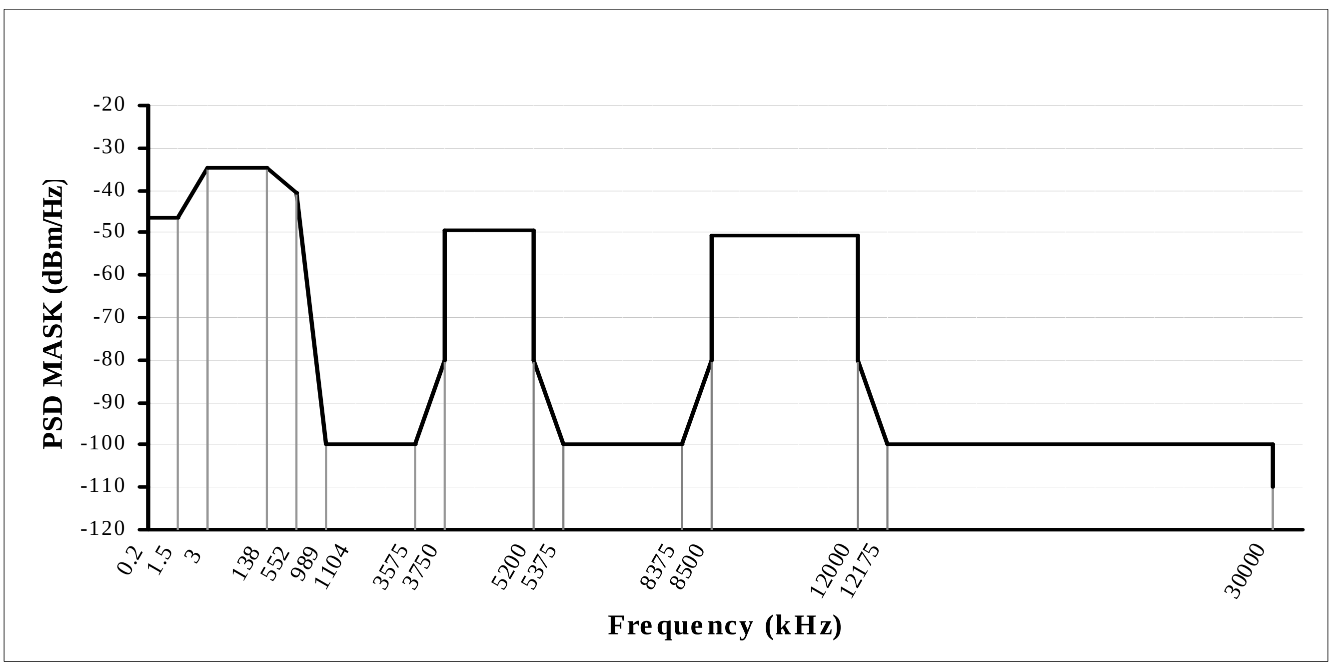


Figure 3.2.1.17(e): VDSL2 ADLU-128 profiles 12a, 12b and 17a upstream all digital mode operation PSD

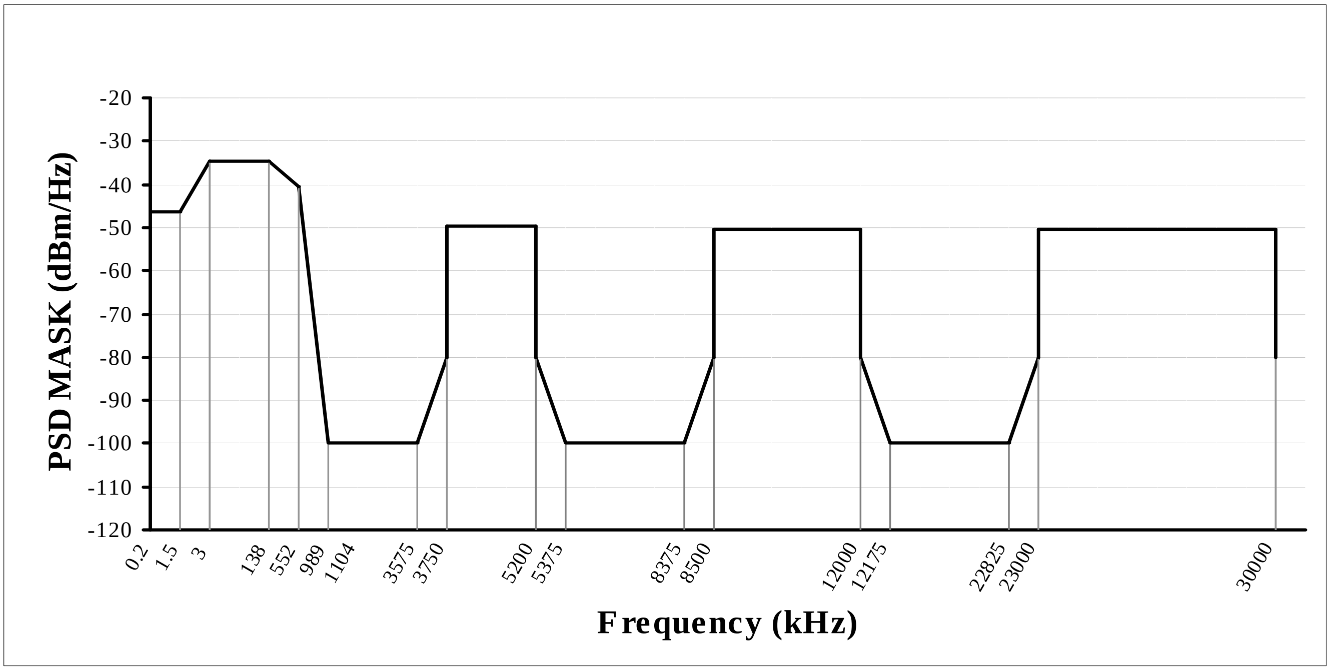


Figure 3.2.1.17(f): VDSL2 ADLU-128 profile 30a upstream all digital mode operation PSD mask

3.2.2 Method of Measurement

(1) Connect the xDSL equipment as shown in Figure 3.2.2.

(2) Operate the xDSL equipment (xTU-R working without xTU-C) and force it to transmit at maximum power.

(3) Set S1 to position "A" (four-pole switch).

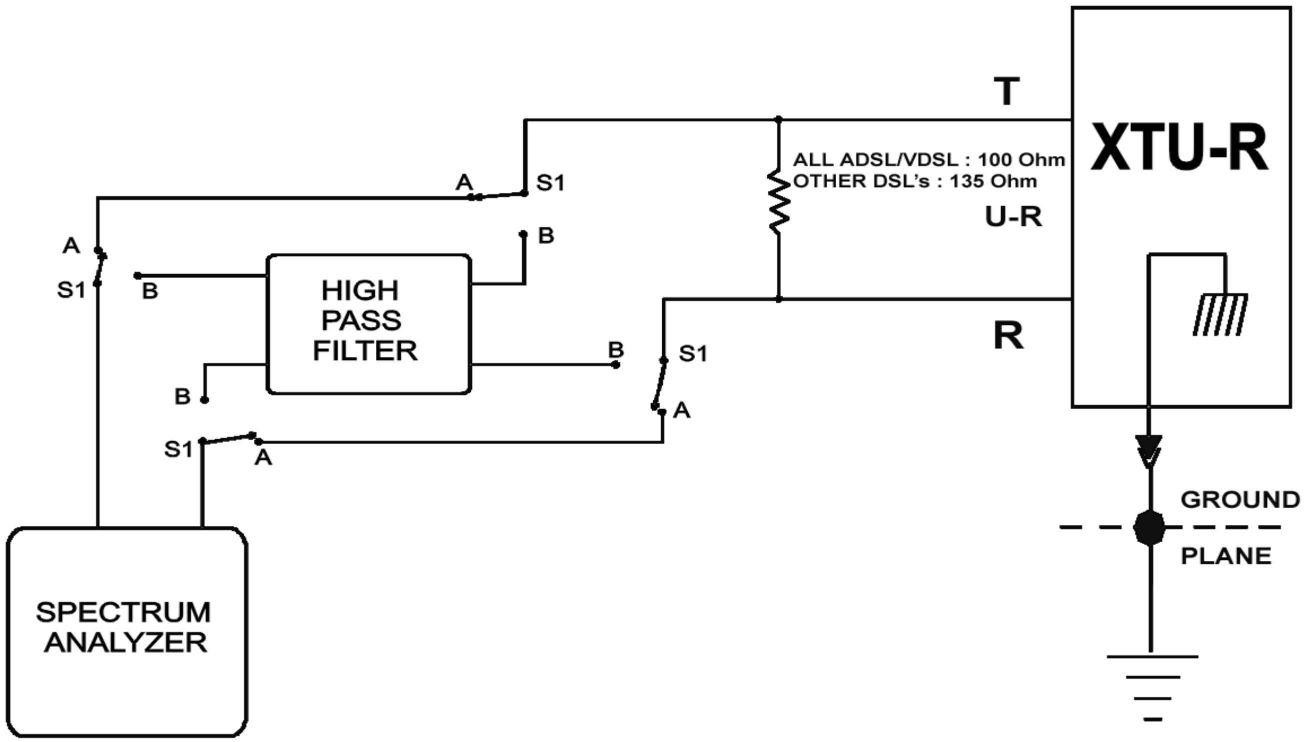
(4) Set the spectrum analyzer to capture the top portion of the upstream band with a suggested resolution bandwidth of 10 kHz and video bandwidth of 100 Hz.

(5) Evaluate the TE signal for compliance with the appropriate spectrum mask using an impedance of 100 ohms for ADSL/VDSL/VDSL2, and 135 ohms for HDSL/HDSL2/HDSL4/ SDSL/SHDSL.

(6) Set S1 to position "B" (four-pole switch).

(7) Set an appropriate filter to cut the signal pass band (working band).

(8) Evaluate the TE signal for compliance with the spectrum mask in the lower and upper out-of-band region using an impedance of 100 ohms for ADSL/VDSL/VDSL2 and 135 ohms for HDSL/HDSL2/HDSL4/SDSL/SHDSL.



Note: When the TE makes provision for an external connection to ground (G), the TE shall be connected to ground. When the TE makes no provision for an external ground, the TE shall be placed on a ground plane which is connected to ground and has overall dimensions at least 50% greater than the corresponding dimensions of the TE. The TE shall be centrally located on the ground plane without any additional connection to ground.

The above is an illustrative test diagram. If the spectrum analyzer has an unbalanced input, an external differential amplifier or balun transformer should be used. Additional high pass filtering may also be necessary to increase measurement sensitivity when making low level PSD measurements.

Figure 3.2.2: xDSL Power Spectral Density (xTU-R Band = Upstream Transmitted Signal for all DSL Technologies)

3.3 Total Signal Power

3.3.1 Requirements

3.3.1.1 ADSL, ADSL2, ADSL2+ and READSL2 Total Signal Power at the U-R Interface Points

The total upstream signal power shall not exceed 13 dBm where the termination impedance is 100 ohms.

3.3.1.2 2B1Q SDSL Total Signal Power

The TE must be tested at least at the maximum data rate for each spectrum management class that the TE is capable of operating in.

The equipment must comply with the applicable power limit when operated at every data rate that the TE can achieve.

Excluding remote power feeding, the average power of a signal consisting of equiprobable symbols in all positions shall not exceed 14 dBm over the frequency band of 0 Hz to symbol frequency (which is equal to one-half of the line bit rate) into a termination of 135 ohms.

3.3.1.3 HDSL [2B1Q] Total Signal Power

Excluding remote power feeding, the average total power of a signal consisting of a framed sequence of symbols with a frame word and equiprobable symbols in all other positions shall not exceed 14 dBm over the frequency band from 0 Hz to 784 kHz into a termination of 135 ohms.

3.3.1.4 HDSL [CAP] Total Signal Power

Excluding remote power feeding, the average transmit power at the transmitter output shall not exceed 14 dBm (high power mode) or 8 dBm (low power mode) into a termination of 135 ohms.

3.3.1.5 HDSL2 Total Signal Power

The total average transmit power may be tested while span powered or locally powered as required by the intended application of the TE. For span powered applications, if the TE is an H2TU-R, the test shall be performed with power (DC voltage) applied at the loop interface (Tip/Ring) by an external voltage source feeding through an AC blocking impedance. The test circuit must contain provisions for DC power feed and possibly transformer isolation for the measurement instrumentation. Note that the DC current source/sink must present a high impedance (at signal frequencies) to common ground.

The total average transmit power of the H2TU-R (into 135 ohms) below 350 kHz shall not exceed 17.0 dBm.

3.3.1.6 SHDSL (Symmetric) Total Signal Power

The total average signal power below f_{sym} transmitted by the SHDSL TU-R shall not exceed 14 dBm, where the termination impedance is 135 ohms.

3.3.1.7 HDSL4 Total Signal Power at the U-R Interface

The total signal power transmitted by HDSL4 TU-R below 307 kHz shall not exceed 14.6 dBm, where the termination impedance is 135 ohms.

3.3.1.8 VDSL [QAM/DMT] and VDSL2 Total Signal Power at the U-R Interface Points

The total upstream signal power shall not exceed 14.5 dBm when operated at every data rate that the TE can achieve, where the termination impedance is 100 ohms. The TE must be tested at least at the maximum data rate in which the TE is capable of operating.

3.3.2 Total Signal Power - Method of Measurement for all DSL Technologies

Note: The total average transmit power may be tested while the TE is span-powered or locally powered as required by the intended application of the TE. For span-powered applications, if the TE is a TU-R, the test shall be performed with the DC power applied at the loop interface by an external voltage source feeding through an AC blocking impedance. The DC current source/sink must present a high impedance (at signal frequencies) to common ground.

(1) Connect the xDSL equipment as shown in Figure 3.2.2.

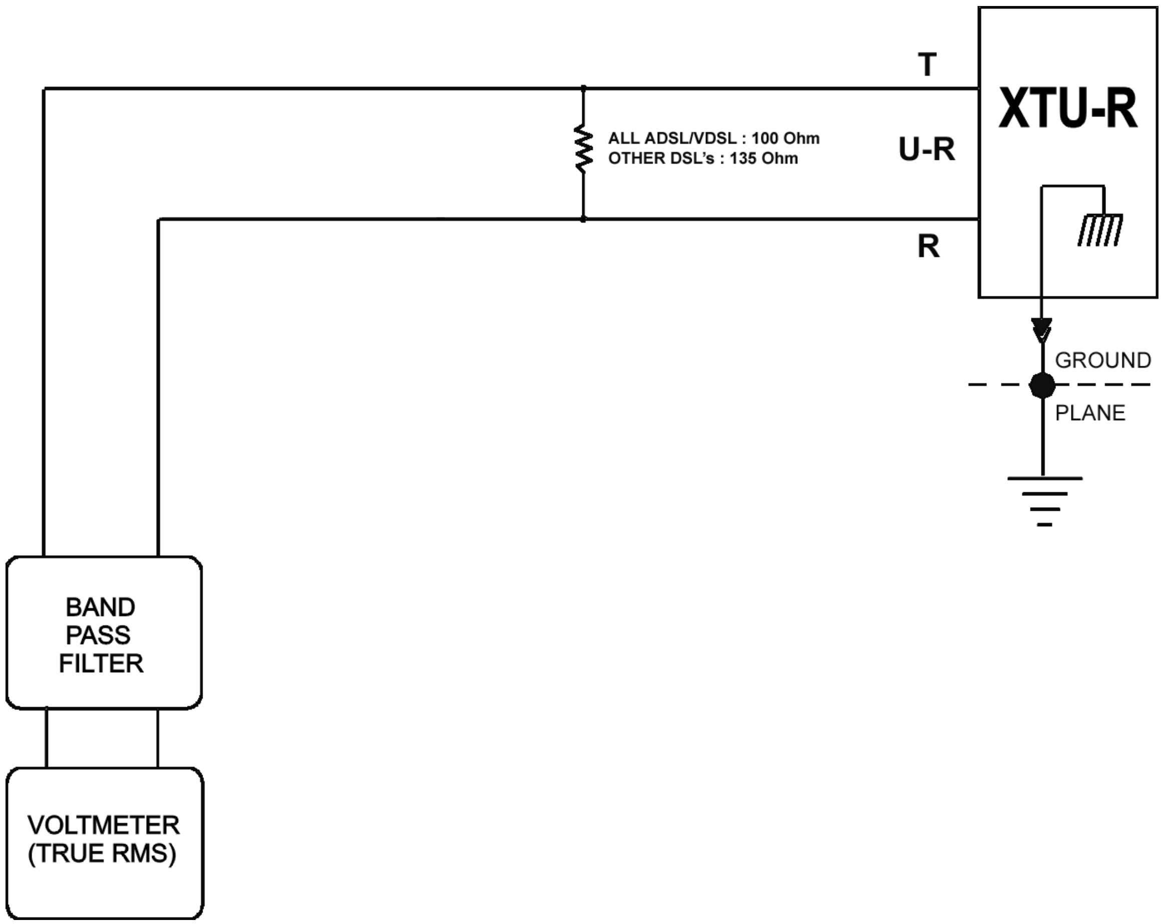
(2) Set the spectrum analyzer to capture the upstream band with a suggested resolution bandwidth of 1 kHz and video bandwidth of 100 Hz.

(3) Measure and record the nominal 3 dB roll off points.

(4) Connect the xDSL equipment as shown in Figure 3.3.2.

(5) Operate the xDSL equipment (xTU-R working without xTU-C) and force it to transmit at maximum power.

(6) Use the appropriate band pass filter for xTU-R (upstream lower and upper 3 dB points). Measure and record the total signal power in dBm with a termination impedance of 100 ohms for ADSL/VDSL/VDSL2, and 135 ohms for all other DSL types.



Band pass Filter: xTU-R Band; Attenuation Slope = 24 dB/Octave; Insertion Loss 0 dB ±0.5 dB; Input Impedance = 100 kohm minimum in parallel with 50 pF maximum; Output Impedance = 50 ohms; Hum and Noise = 100 uVrms maximum.

Note: When the TE makes provision for an external connection to ground (G), the TE shall be connected to ground. When the TE makes no provision for an external ground, the terminal equipment shall be placed on a ground plane which is connected to ground and has overall dimensions at least 50% greater than the corresponding dimensions of the TE. The TE shall be centrally located on the ground plane without any additional connection to ground.

The above is an illustrative test diagram. If the spectrum analyzer has an unbalanced input, an external differential amplifier or balun transformer should be used. Additional high-pass filtering may also be necessary to increase measurement sensitivity when making low-level PSD measurements.

Figure 3.3.2: xDSL Total Signal Power
(xTU-R Band = Upstream Transmitted Signal for all DSL Technologies)

3.4 Transverse Balance

3.4.1 Requirements

The transverse balance of the TU-R shall exceed the values in Table 3.4(a) over the voice band from 200 Hz to 4000 Hz and over the entire range of frequencies between the lower and upper -20 dB points (relative to peak PSD) of the signal pass band as determined from the appropriate DSL PSD mask, with the Z_L, Z_M and V_M set to the values defined in Tables 3.4(b) to 3.4(f).

Note 1: When using the actual -20 dB points from the transmitted signal to define the frequency range, the TE shall be transmitting at maximum power.

Note 2: Table 3.4(a) specifies the limits for the entire frequency range. Please note that you only have to test the TE to the applicable frequency range, which in most cases is between 200 Hz and 4 kHz (voice band) and from 12 kHz to 30 MHz (-20 dB points). All other frequency ranges below or above the -20 dB points are not applicable even if shown in Table 3.4(a).

Transverse balance is a comparison of the voltage of a transmitted metallic signal to the voltage of any resulting longitudinal signal. It is defined in dB as:

Transverse Balance $_{M - L} = 20 \log_{10}[V_M(f)/V_L(f)]$

where $V_M(f)$ = the metallic voltage at frequency f applied across tip and ring conductors of the port under test by a balanced source with metallic impedance Z_M, and $V_L(f)$ = the resultant longitudinal voltage appearing across a longitudinal impedance Z_L. The greater the V_M to V_L ratio, the better the transverse balance of the transceiver unit and the less likelihood that it will contribute to a crosstalk interference problem. When calibrating the testing arrangement, the source metallic voltage should equal V_M volts when a metallic termination of Z_M is substituted for the equipment under test. For all the different types of DSL, please refers to Tables 3.4(b) to 3.4(f) to find the correct values for metallic impedance Z_M, longitudinal impedance Z_L, and metallic voltage V_M.

3.4.2 Method of Measurement

(1) Connect the TE as shown in Figure 3.4.

(2) Set the spectrum analyzer/tracking generator to sweep the appropriate frequency range. Refer to Table 3.4(a) for the frequency bands. If the actual -20 dB points from the transmitted signal are used to define the frequency range, the TE shall be transmitting at maximum power.

(3) Adjust the tracking generator voltage to the appropriate value for the type of DSL under test, across the calibration test resistor R3, using switch S1. Refer to Tables 3.4(b) to 3.4(f) for the correct values.

(4) Connect the detector across resistor R2.

(5) Adjust the differential trimmer capacitor until a minimum voltage across resistor R2 is obtained. This represents the highest degree to which the bridge can be balanced, and this balance

measurement must be at least 20 dB better than the requirement for the applicable frequency band. If this degree of balance cannot be attained, further attention should be given to the component selection and the construction of the test circuit.

(6) Reverse the polarity using switch S3. If the longitudinal voltage (E_L) changes by less than 1 dB, the calibration is acceptable. If the longitudinal voltage changes by more than 1 dB, it indicates the bridge needs further adjustment to be sufficiently balanced to accurately measure the TE. Repeat the calibration process until the measurements differ by less than 1 dB while maintaining the 20 dB minimum balance noted in step (5) above.

(7) Replace the calibration resistor with the TE, using switch S1 and S2.

(8) Measure the voltage across the tip and ring of the TE. This is the metallic reference voltage (E_M).

(9) Measure the voltage across resistor R2. This is the longitudinal voltage (E_L).

(10) Calculate the balance using the following formula:

Balance M/L (dB) = 20 $\log_{10}$(Vm/Vl)

Notes:

(1) If the readings are taken in dBV, then the equation can be simplified to the following:

Balance M/L (dB) = Vm(dBV) - Vl (dBV)

(2) TE which is not normally grounded should be set in its normal at rest position directly on a grounded plane whose overall dimensions are at least 50% greater than the footprint of the TE. From a transverse balance standpoint, this represents a worst case condition (i.e. the closest proximity to ground that is likely to be encountered by the TE).

(3) Transverse balance may be measured while the TE is line powered or locally powered. If the TE is line powered then the test circuit shall contain a DC voltage source. The test shall be performed with the appropriate DC voltage source applied between the tip and ring conductors through an AC blocking impedance. The DC current source or sink must present high impedance (at signal frequencies) to common ground. In line powered applications, the test circuit shall contain provisions for isolation of the measurement instrumentation from unintentional circuit paths through the common ground of the instrumentation and the TE power feed circuitry.

Table 3.4(a): Minimum Transverse Balance Requirements

Frequency Band	Minimum Transverse Balance
200 Hz < $f \leq$ 12 kHz	40 dB
12 kHz < $f \leq$ 1544 kHz	35 dB
1544 kHz < $f \leq$ 12 MHz	30 dB
12 MHz < f $\leq$ 30 MHz	25 dB

Note: Any range of frequency between the voice band (200 Hz to 4 kHz) and the lower -20 dB point, and any range of frequency above the upper -20 dB point are not applicable, even if shown in Table 3.4(a).

3.4.3 Transverse Balance Testing Criteria

Table 3.4(b): Frequency range of transverse balance requirements for ADSL over POTS

Interface	Frequency range (kHz)	Longitudinal termination (Z_L) (ohms)	Metallic termination (Z_M) (ohms)	Metallic voltage (V_M) (V)
ADSL	13.6 to 1625	90	100	0.316
ADSL2	13.6 to 1625	90	100	0.316
READSL	13.6 to 1625	90	100	0.316
ADSL2+	13.6 to 2425	90	100	0.316

Table 3.4(c): Frequency range of transverse balance requirements for ADSL all digital mode equipment

Interface	Frequency range (kHz)	Longitudinal termination (Z_L) (ohms) (Note)	Metallic termination (Z_M) (ohms)	Metallic voltage (V_M) (V)
ADSL2	0.2 to 2425	90 or 500	100	0.316
ADSL2+	0.2 to 2425	90 or 500	100	0.316

Table 3.4(d): Frequency range of transverse balance requirements for SHDSL, ESHDSL, HDSL2 and HDSL4 equipment

Interface	Frequency range (kHz)	Longitudinal termination (Z_L) (ohms) (Note)	Metallic termination (Z_M) (ohms)	Metallic voltage (V_M) (V)
SHDSL	0.2 to 490	90 or 500	135	0.367
ESHDSL	0.2 to 761	90 or 500	135	0.367
HDSL2	0.2 to 422	90 or 500	135	0.367
HDSL4	0.2 to 494	90 or 500	135	0.367

Table 3.4(e): Frequency range of transverse balance requirements for 2B1Q SDSL

Interface	Frequency range (kHz)	Longitudinal termination (Z_L) (ohms) (Note)	Metallic termination (Z_M) (ohms)	Metallic voltage (V_M) (V)
2B1Q SDSL	0.2 to 575	90 or 500	135	0.367

Table 3.4(f): Frequency range of transverse balance requirements for VDSL and VDSL2

Interface	Frequency range (kHz)	Longitudinal termination (Z_L) (ohms) (Note)	Metallic termination (Z_M) (ohms)	Metallic voltage (V_M) (V)
VDSL over POTS	13.6 to 12000	90	100	0.316
VDSL2 over POTS profiles 8a, 8b, 8c, and 8d	13.6 to 8500	90	100	0.316
VDSL2 over POTS profiles 12a and 12b	13.6 to 12000	90	100	0.316
VDSL2 over POTS profiles 17a	13.6 to 20500	90	100	0.316
VDSL2 over POTS profile 30a	13.6 to 30000	90	100	0.316
VDSL2 all digital mode profiles 8a, 8b, 8c, and 8d	0.2 to 8500	90/500	100	0.316
VDSL2 all digital mode profiles 12a and 12b	0.2 to 12000	90/500	100	0.316
VDSL2 all digital mode profile 17a	0.2 to 20500	90/500	100	0.316
VDSL2 all digital mode profile 30a	0.2 to 30000	90/500	100	0.316

Note: The longitudinal impedance (Z_L) shall be 500 ohms for frequencies from 200 Hz to 12 kHz, and 90 ohms for frequencies above 12 kHz.

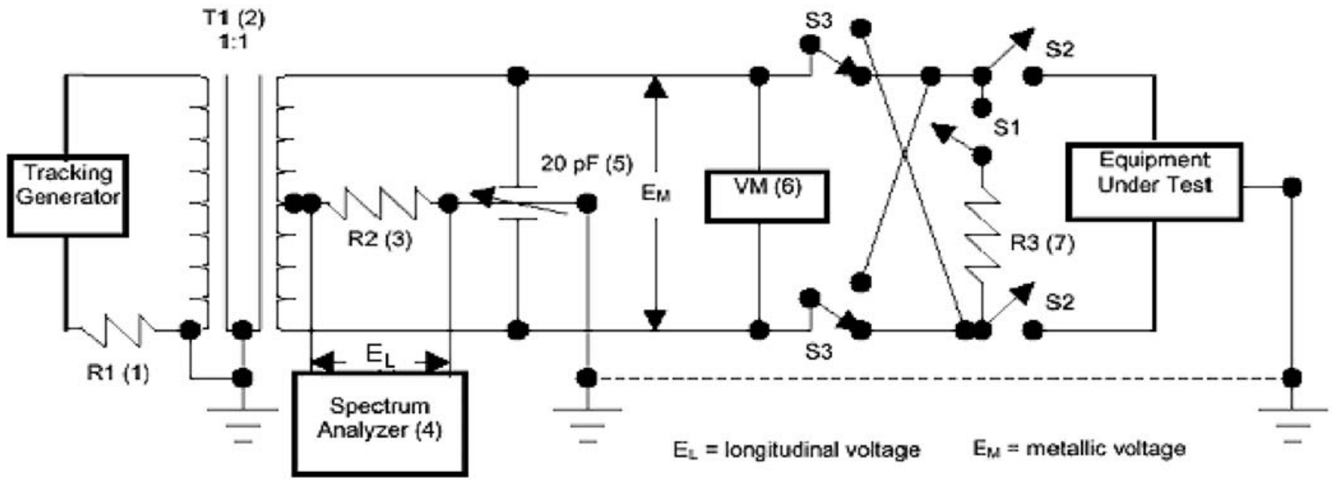


Figure 3.4: Illustrative Test Configuration for Transverse Balance Conformance Testing

1 - Combined resistance of R1 and tracking generator output resistance shall equal TE impedance (100 or 135 ohms).
2 - Use center-tapped 1:1 transformer (e.g. Midcom 671-5767 or equivalent).
3 - R2 provides the desired longitudinal impedance using 90 ohms or 500 ohms metal film or other non-inductive resistor.
4 - High impedance spectrum analyzer or frequency selective voltmeter. It may be unbalanced.
5 - Differential trimmer capacitor, 2.4 to 24.5 pF, Johnson 189-0759-005 or equivalent.
6 - Any high impedance balanced or floating voltmeter with adequate frequency response. It need not be frequency selective.
7 - R3 provides the desired calibration impedance. Should be a 100 or 135 ohm metal film or other non-inductive resistor.

3.5 Longitudinal Output Voltage

Compliance with the limits for each DSL type is required with a longitudinal termination which has an impedance equal to or greater than a 100 ohms resistor in series with a 0.15 µF capacitor. The longitudinal output voltage in all 4 kHz frequency bands (averaged over a minimum period of 1 second) shall not exceed the values in Tables 3.5(a) and 3.5(c) over the indicated range of frequencies between the lower and upper -30 dB points (relative to peak PSD) of the signal pass band as determined from the appropriate PSD mask for the DSL type. Use appropriate lower, upper, and 4x upper -30 dB points for each DSL type. The actual -30 dB points from the transmitted signal may also be used to define the frequency range. The metallic test impedance Z_M is defined in Tables 3.4(b) to 3.4(f).

Note: When using the actual - 30 dB points from the transmitted signal to define the frequency range, the TE shall be transmitting at maximum power.

3.5.1 Method of Measurement

(1) Connect the TE as shown in Figure 3.5.

(2) Set the spectrum analyzer to sweep the appropriate frequency range for the operating band of the DSL system tested. If the actual -30 dB points from the transmitted signal are used to set the frequency bands, the TE shall be transmitting at maximum power.

(3) Measure and record the true rms longitudinal voltage in all 4 kHz frequency bands, averaged over a minimum period of 1 second. An alternative resolution bandwidth of 3 kHz may be used provided that either the limits are reduced by 1.3 dB (to -51.3 dBV or -81.3 dBV) or the readings are corrected by adding 1.3 dB.

(4) Compare the values obtained in step (3) with the limits of Tables 3.5(a) and (c).

(5) Set the spectrum analyzer to sweep the appropriate frequency range for the out-of-band region of the DSL system tested. Refer to Tables 3.5(a) and (c) for the frequency bands or use the actual -30 dB points from the transmitted signal to set the frequency bands. If the actual -30 dB points from the transmitted signal are used to set the frequency bands, the TE shall be transmitting at maximum power.

(6) Repeat steps (3) and (4) for the out-of-band frequency range.

Table 3.5(a): Maximum Longitudinal Output Voltage limit for VDSL2 terminal equipment

Frequency Band (kHz) (notes 1 and 2)	**Maximum longitudinal output voltage (dBVrms) in all 4 kHz bands averaged over a minimum period of 1 second (Note 3)**			
	Profiles 8a, 8b, 8c, and 8d	**Profiles 12a and 12b**	**Profile 17a**	**Profile 30a**
f_a (note 1) to f_b (note 2)	-50	-50	-50	-50
f_b (note 2) to 3750	-80	-80	-80	-80
3750 to 5200	-50	-50	-50	-50
5200 to 8500	-80	-80	-80	-80
8500 to 12000		-50	-50	-50
12000 to 21000		-80	-80	-80
21000 to 23000			-80	-80
23000 to 30000			-80	-50

Notes:

(1) Frequency f_a is 0.1 kHz for all digital modes and 12 kHz for operating modes designed to work on the same loop as a voice band service such as POTS.

(2) Frequency f_b is the frequency at which the PSD mask is approximately 30 dB below the peak mask value. The f_b values for various VDSL2 upstream PSD masks are given in Table 3.5(b).

(3) If a 3 kHz measurement bandwidth is used rather than the 4 kHz bandwidth on which the requirements are based, a 1.3 dB correction factor for the smaller measurement bandwidth is applied to the maximum longitudinal output voltage limits, thus decreasing -50 dBV limits to -51.3 dBV and -80 dBV limits to -81.3 dBV respectively.

Table 3.5(b): Values of fb for various VDSL2 upstream PSD masks

Operating with POTS designator	**All-digital mode designator**	f_b **(kHz)**
EU-32	ADLU -32	184
EU-36	ADLU -36	207
EU-40	ADLU -40	230
EU-44	ADLU -44	253
EU-48	ADLU -48	276
EU-52	ADLU -52	299
EU-56	ADLU -56	322
EU-60	ADLU -60	345
EU-64	ADLU -64	368
EU-128	ADLU-128	741

Table 3.5(c): Maximum Longitudinal Output Voltage (LOV) for technologies other than VDSL2

Interface	**Applicable Frequency Range**	**Max. LOV (dBVrms) averaged over 1 sec. in all 4 kHz frequency bands**	**Max. LOV (dBVrms) averaged over 1 sec. in all 3 kHz frequency bands (Note 4)**
ADSL, ADSL2, ADSL2+, RADSL2 over POTS (Notes 1 and 2)	10 < f < fb fb < f < 4fb	-50 -80	-51.3 -81.3
ADSL, ADSL2, ADSL2+ all-digital-mode (Notes 2 and 3)	0.1 < f < fb fb < f < 4fb	-50 -80	-51.3 -81.3

SDSL, SHDSL, ESHDSL	Operating Band From upper -30 dB (relative to peak PSD) frequency to 4 x the upper -30 dB frequency	-50 -80	-51.3 -81.3
HDSL2, HDSL4	Operating Band From upper -30 dB (relative to peak PSD) frequency to 4 x the upper -30 dB frequency	-50 -80	-51.3 -81.3

Notes:

(1) The first frequency band is the operating band limited by the frequency point fb, the frequency at which the PSD is approximately 30 dB down from the peak mask value. For ADSL modems that do not support extended upstream operation, this frequency is 211 kHz, so the maximum frequency to which the longitudinal output voltage is measured in the upper band is 844 kHz.

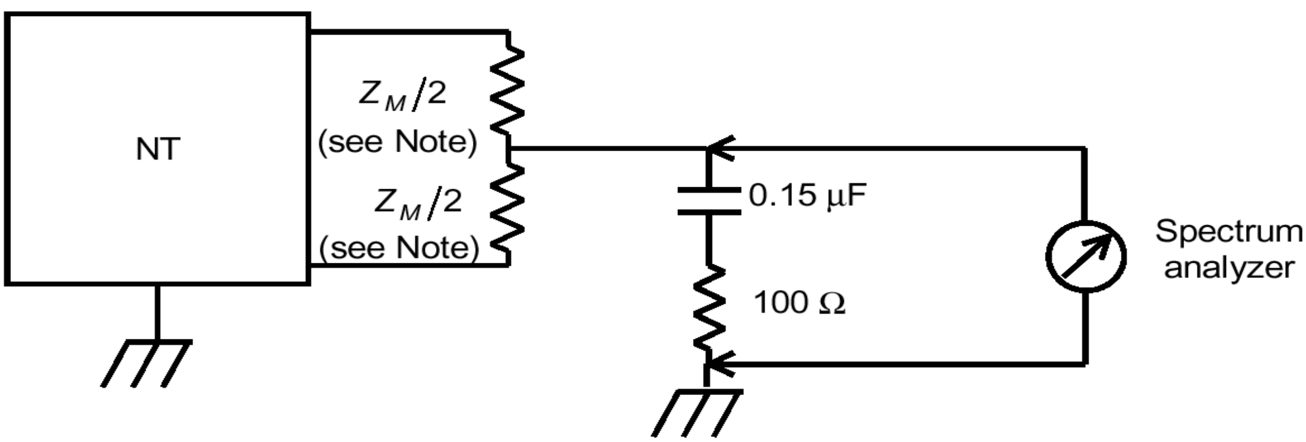
(2) Alternatively, the measured 30 dB points may be used to define the operating band's lower and upper frequency points.

(3) The first frequency band is the operating band limited by the frequency point fb, the frequency at which the PSD is approximately 30 dB down from the peak mask value. See Table 3.5(d) for the values of frequencies fb.

(4) This option include a -1.3 dB correction factor associated with using a 3 kHz bandwidth rather than the ideal 4 kHz bandwidth.

Table 3.5(d): Values of fb for various all digital mode extended upstream PSD masks

Upstream mask-number	All digital mode designator	f_b (kHz) (with 72 dB/octave between f1 and f_int.)	f_b (kHz) (with 48 dB/octave between f1 and f2)
1	ADLU-32	184	213
2	ADLU-36	207	239
3	ADLU-40	230	266
4	ADLU-44	253	293
5	ADLU-48	276	319
6	ADLU-52	299	346
7	ADLU-56	322	372
8	ADLU-60	345	399
9	ADLU-64	368	426



Note: These resistors to be matched better than 0.1% tolerance.
NT refers to Network Termination.

Figure 3.5: Measurement Method for Longitudinal Voltage

Annex A - Deployment Guidelines

To ensure spectral compatibility with other xDSL technologies deployed in the loop plant (i.e. to avoid third party harm), ADSL, ADSL2, ADSL2+, HDSL, HDSL2, SDSL, SHDSL, HDSL4, VDSL and VDSL2 systems should not be deployed on loops longer than the Equivalent Working Length (EWL) identified below:

Table 1(a): Deployment Guidelines

xDSL	Maximum EWL
ADSL	All non-loaded loops
ADSL2, ADSL2+	See Table 1(b)
HDSL	2750 m (9000 ft)
HDSL2	3200 m (10,500 ft)
2B1Q SDSL	See Table 1(c)
SHDSL	See Table 1(d)
HDSL4	All non-loaded loops
VDSL	All non-loaded loops
VDSL2	All non-loaded loops

Equivalent Working Length (EWL) is defined as:

$$EWL = L_{26} + 0.75 (L_{24}) + 0.60 (L_{22}) + 0.40 (L_{19})$$

Where L_{26} is the length of 26 AWG cable, L_{24} is the length of 24 AWG cable, L_{22} is the length of 22 AWG cable, and L_{19} is the length of 19 AWG or larger gauge cable in the assigned loop.

xDSL transceivers using asymmetric spectra (ADSL, HDSL2, HDSL4) shall not be installed with a transceiver (TU-C) transmitting in the downstream frequency band (ADSL: 138-1,104 kHz, HSDL2: 0- 440 kHz, HDSL4: 0-600 kHz) located at the customer end of the loop (customer premises).

The administrative procedures to be used by Local Exchange Carriers or other service providers to ensure that systems are installed on loops meeting these deployment guidelines are beyond the scope of this document.

Table 1(b): Deployment Guidelines for ADSL2 All Digital Mode Range Extended Upstream

Mask Number	Upstream Mask Designator	ADSL Deployment Guideline, EWL (m)
1	ADLU-32	> 4725 (15.5 kft)
2	ADLU-36	3353 (11.0 kft)
3	ADLU-40	3201 (10.5 kft)
4	ADLU-44	3048 (10.0 kft)
5	ADLU-48	2896 (9.5 kft)
6	ADLU-52	2896 (9.5 kft)
7	ADLU-56	2744 (9.0 kft)
8	ADLU-60	2744 (9.0 kft)
9	ADLU-64	2744 (9.0 kft)

Table 1(c): Deployment Guidelines for 2B1Q SDSL

PSD	Maximum 2B1Q SDSL Line Bit Rate (kbps)	2B1Q SDSL Deployment Guideline, EWL (m)
SM1 PSD Mask	300	all non-loaded loops
$SDSL_u$ (f) with f_{sym} = 160000	320	4725 (15.5 kft)
$SDSL_u$ (f) with f_{sym} = 168000	336	4420 (14.5 kft)
$SDSL_u$ (f) with f_{sym} = 192000	384	4115 (13.5 kft)
$SDSL_u$ (f) with f_{sym} = 200000	400	4115 (13.5 kft)
$SDSL_u$ (f) with f_{sym} = 208000	416	3965 (13 kft)
$SDSL_u$ (f) with f_{sym} = 232000	464	3810 (12.5 kft)
$SDSL_u$ (f) with f_{sym} = 264000	528	3660 (12 kft)
$SDSL_u$ (f) with f_{sym} = 296000	592	3505 (11.5 kft)
$SDSL_u$ (f) with f_{sym} = 328000	656	3355 (11 kft)
$SDSL_u$ (f) with f_{sym} = 360000	720	3200 (10.5 kft)
$SDSL_u$ (f) with f_{sym} = 392000	784	3050 (10 kft)
$SDSL_u$ (f) with f_{sym} = 456000	912	2895 (9.5 kft)
$SDSL_u$ (f) with f_{sym} = 488000	976	2745 (9 kft)
$SDSL_u$ (f) with f_{sym} = 552000	1104	2590 (8.5 kft)
$SDSL_u$ (f) with f_{sym} = 616000	1232	2440 (8 kft)
$SDSL_u$ (f) with f_{sym} = 712000	1424	2285 (7.5 kft)
$SDSL_u$ (f) with f_{sym} = 840000	1680	2135 (7 kft)
$SDSL_u$ (f) with f_{sym} = 936000	1872	1980 (6.5 kft)
$SDSL_u$ (f) with f_{sym} = 1064000	2128	1830 (6 kft)
$SDSL_u$ (f) with f_{sym} = 1128000	2256	1675 (5.5 kft)
$SDSL_u$ (f) with f_{sym} = 1160000	2320	1525 (5 kft)

Table 1(d): Deployment Guidelines for SHDSL

SHDSL Line Bit Rate (kbps)	SHDSL Deployment Guideline EWL (m)
LBR < 592	all non-loaded loops
600 < LBR < 616	4770 (15.0 kft)
624 < LBR < 628	4420 (14.5 kft)
656 < LBR < 688	4265 (14.0 kft)
696 < LBR < 800	4115 (13.5 kft)
808 < LBR < 832	3810 (12.5 kft)
840 < LBR < 896	3660 (12.0 kft)
904 < LBR < 952	3965 (13.0 kft)
960 < LBR < 1000	3810 (12.5 kft)
1008 < LBR < 1088	3660 (12.0 kft)
1096 < LBR < 1160	3505 (11.5 kft)
1168 < LBR < 1320	3355 (11.0 kft)
1328 < LBR < 1472	3200 (10.5 kft)
1480 < LBR < 1536	3050 (10.0 kft)
1544 < LBR < 1552	3200 (10.5 kft)
1560 < LBR < 1664	3050 (10.0 kft)
1672 < LBR < 1880	2895 (9.5 kft)
1888 < LBR < 2008	2745 (9.0 kft)
2016 < LBR < 2320	2590 (8.5 kft)

Annex B - Informative References

[1] T1.417 - 2001: Spectrum Management for Loop Transmission Systems

[2] ITU-T Recommendation K.50, G.992.3, G.992.5, G.993.2

[3] T1 TRQ - XX: Technical Requirements for Maximum Voltage, Current and Power Levels for Network-Powered Transport Systems

[4] CAN/CSA-C22.2 NO. 60950-00: Safety of Information Technology Equipment

[5] T1.424/Trial-Use - Interface Between Networks and Customer Installations—Very-high Speed Digital Subscriber Lines (VDSL) Metallic Interface

[6] T1E1.4/2002-002 - Draft proposed American National Standard, Spectrum Management for Loop Transmission Systems, Issue 2