

Guidelines on the Use of DSL Transmission Systems in the BT Access Network

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Foreword

This document has been produced by the NICC Task Group on Digital Subscriber Line (DSL). Representatives from network operators, switch and terminal equipment manufacturers, test laboratories and Ofcom participated in the Task Group.

This document includes reference to and extracts from White Papers published by the Broadband Forum (at <https://www.broadband-forum.org/resources>). The DSL Task Group wishes to acknowledge and express its appreciation to the Broadband Forum for permission to include these references and extracts.

Introduction

As part of the Local Loop Unbundling (LLU) project in the UK, the NICC DSL Task Group developed Access Network Frequency Plans (ANFP) for both the BT [1] and KCH [2] networks. These ANFP specifications are necessary in order to manage crosstalk interference, particularly between xDSL systems, operating over a public access network in the multi-operator environment resulting from LLU.

Compliance with the relevant ANFP is a necessary requirement for all users of the access network, in order to ensure crosstalk interference is controlled. Hence the ANFP determines what xDSL systems can be connected at agreed connections points in the access network and in what configuration.

This document provides guidance on the implementation of xDSL systems to ensure compliance with the relevant part of the ANFP. Whilst every effort has been taken to ensure the accuracy of this document, in the event of an inconsistency with the relevant ANFP, the ANFP is the normative text. ***In particular, the obligation on users of the access network is to comply with the relevant ANFP, not with this document.***

This document is an updated version of ND1405:2016/04 to take account of the updating of the BT ANFP to version 7.2.1 [1]. This update of the BT ANFP is fully backward compatible with the previous version.

The major change in ANFP version 7 enables the FAST 212MHz profile, reduced start frequency for FAST, full ITU downstream VDSL2 PSD mask, higher CAL values from 54 to 72, optimised UPBO for systems with crosstalk cancellation and an increased downstream FAST PSD for use on underground cables

1 Scope

The scope of this guideline is restricted to covering the use of xDSL systems designed to international standards on the BT access network, configured and operated to comply with the currently (i.e. at the date of publication of this document) defined BT ANFP [1].

It is recognised that xDSL technology and their related international standards continue to be developed. Equally, there may be further discussion in the NICC DSL Task Group on potential amendments to the BT ANFP. This document may be updated to take account of new, internationally standardised xDSL systems and/or revision to the BT ANFP.

Note: This document only considers transmission systems operating over the BT access network. When private networks are connected to the BT access network, signals from the private network transmitted on to the BT access network need to comply with the ANFP. A separate document [3] discusses and gives guidance on this issue.

2 References

2.1 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

- [1] Specification of the Access Network Frequency Plan applicable to transmission systems used on the BT Access Network V7.2.1 – ND1602:2019-10 (available on NICC website at <https://niccstandards.org.uk/publications/>)

2.2 Informative references

- [2] Specification of the Access Network Frequency Plan applicable to transmission systems used on the KCH Access Network – ND1604:2012/03 (available on NICC website at <https://niccstandards.org.uk/publications/>)
- [3] Report on the Mutual Compatibility of Transmission Systems used in Public Access & Private Networks - ND1506:2004/11 (available on NICC website at <https://niccstandards.org.uk/publications/>)
- [4] Directive 2014/30/EU on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (available at <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0030>)
- [5] Operation of G.fast below 17.7 MHz in VDSL spectrum - ND1520 2018/07 (available on NICC website at <https://niccstandards.org.uk/publications/>)
- [6] Data Sharing for DSM – ND1518 2015/09 (available on NICC website at <https://niccstandards.org.uk/publications/>)
- [7] Assessment of the theoretical limits of copper in the last mile. Report prepared by Sagentia for Ofcom. July 2008.
https://www.ofcom.org.uk/_data/assets/pdf_file/0024/27564/asses.pdf

3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ADSL	Asymmetric Digital Subscriber Line
ANFP	Access Network Frequency Plan
BT	British Telecommunications plc.
CAL	Cabinet Assigned Loss
CGAL	Co-ordinated Group Assigned Loss - a parameter that describes the electrical length of the cables between an SDF site and a connected G-SLCP.
CPE	Customer Premises Equipment
CS	Cancellation Status
DPBO	Downstream Power Back-Off
DPU	Distribution Point Unit
DSL	Digital Subscriber Line - any of the modem technologies that send high-speed data over metallic telephone pairs. A DSL line has a dedicated modem at each end of the physical wire pair; typically one of these is in the exchange
DSLAM	Digital Subscriber Line Access Multiplexer
EFM	Ethernet in the First Mile
EMC	Electromagnetic compatibility
ETSI	European Telecommunications Standards Institute
FAST	Fast Access to Subscriber Terminals
FSTART	Start frequency for FAST allowing control over spectrum allocation
G.fast	Refers to FAST
G-SDF	Co-ordinated Group Sub-loop Distribution Frame - often located at the cabinet or DPU.
G-SLCP	Co-ordinated Group Sub Loop Connection Point - located at the G-SDF.
HDSL	High bit rate Digital Subscriber Line
ITU-T	International Telecommunication Union - Telecom Standardization
KCH	Kingston Communications (Hull) plc., Member of the KCOM Group
LLU	Local Loop Unbundling
LLUO	Local Loop Unbundling Operators
LPM	Limit PSD Mask

MDF	Main Distribution Frame
MIB	Management Information Base
NICC	Network Interoperability Consultative Committee a committee of UK industry set up to advise Ofcom (and previously, Oftel) homepage: https://niccstandards.org.uk
NTP	Network Termination Point
PCP	Primary Connection Point
POTS	Plain Ordinary Telephone Service - analogue voice band telephony
PSD	Power Spectral Density
SDF	Sub-loop Distribution Frame – the equipment block which terminates the sub-loop access network cables. This is inside a SLCP.
SDSL	Symmetric single pair high bitrate Digital Subscriber Line A term used in ETSI to refer to SHDSL. This should not be confused with the USA use of the term 'SDSL' which refers to DSL systems similar to HDSL.
SHDSL	Single-pair High-speed Digital Subscriber Line
SLCP	Sub Loop Connection Point – the flexibility point in BT's network at which the network is opened for access to the sub loop. Colloquially the term 'cabinet' has been used.
UPBO	Upstream Power Back-Off – power control applied at the customer end modems so that crosstalk from short lines does not disable use of long lines.
xDSL	any variant of DSL modem e.g. ADSL, HDSL, SHDSL, VDSL or FAST
VDSL	Very high speed Digital Subscriber Line, (refers to VDSL2, G.993.2)
VDSL1	Very high speed Digital Subscriber Line, G.993.1
TDD	Time Division Duplexing

4 Compliance with the ANFP

BT ANFP [1] Section 3 (ANFP Conformance and Interference Management) describes the requirements and process for ensuring ANFP compliance. In particular, it should be noted that all equipment connected to the BT access network (i.e. BT equipment, LLU Operator equipment and CPE) needs to comply with the ANFP.

Demonstration of compliance is via a system of self-declaration. A test specification is defined in the ANFP (Sections 2.2.2 and 4 of the ANFP [1]) to allow verification of compliance. It is the responsibility of the organisation implementing and operating the equipment to ensure and maintain its compliance to the ANFP.

5 Application of the BT ANFP

The BT ANFP [1] defines the requirements in terms of specifying the location points in the access network where transmission equipment can be connected and the maximum transmit power that can be injected at those points. This maximum transmit power is defined by a PSD (power spectrum density) mask, or through the dynamic PSD mask specification as defined in Section C.3.2 of the ANFP and described in Section 6.11.3 of this document.

Figures 1a and 1b (taken from the BT ANFP) show the points in the BT access network at which the ANFP applies. The equipment configurations illustrate dedicated (i.e. not shared) and shared, full loop Metallic Path Facility (MPF) and sub-loop scenarios. The location of equipment (i.e. modems and splitters) at the Main Distribution Frame (MDF) site and near the Sub Loop Connection Point (SLCP), and the wiring arrangements for the splitter filters, are illustrative only and do not necessarily represent actual implementation.

The ANFP applies to the signal levels at the actual point of connection to the BT metallic access network i.e. at the MDF, Sub-loop Distribution Frame (SDF) or Network Termination Point (NTP).

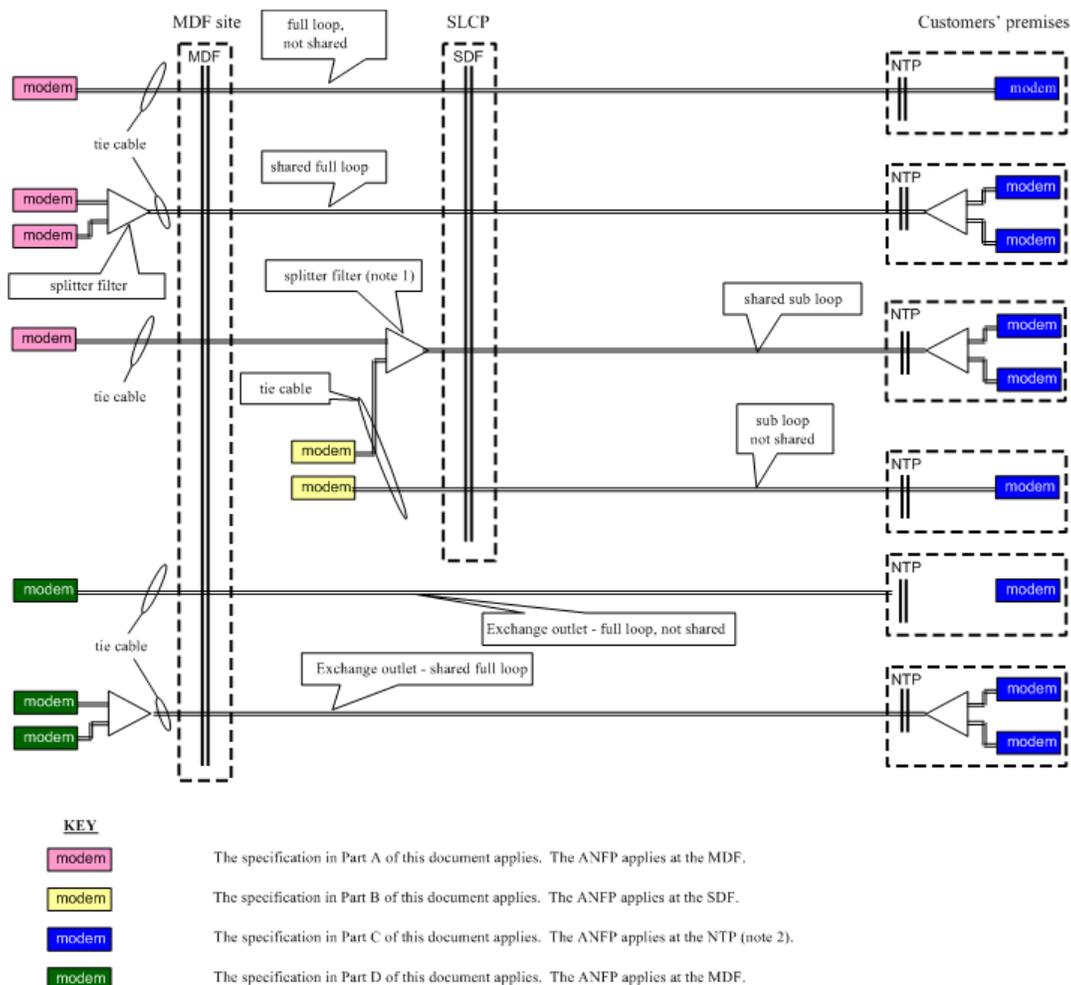


Figure 1a – Application of the ANFP, scenarios Part A to D only

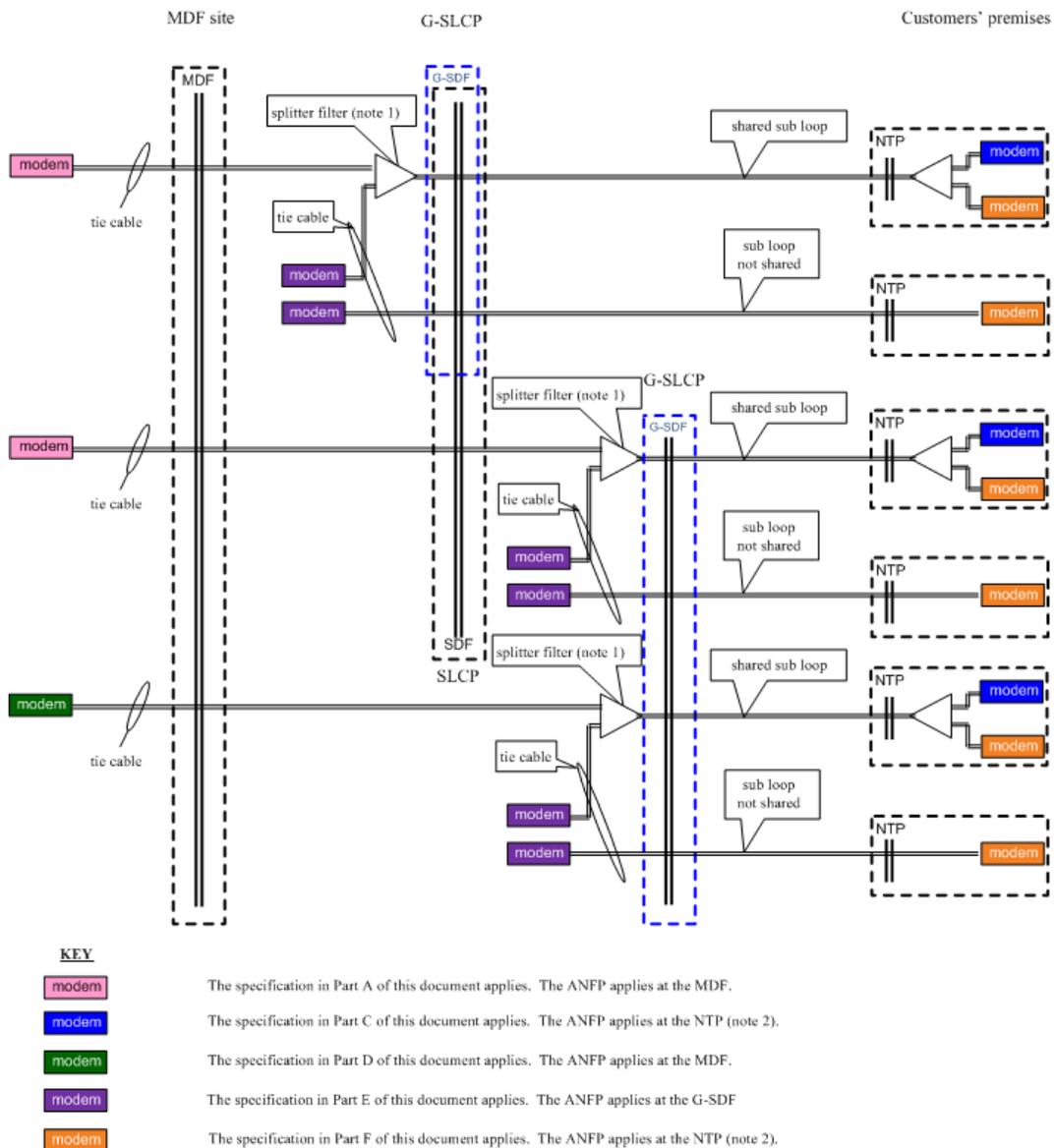


Figure 1b – Application of the ANFP, scenarios including Parts E and F

For each point of application of the ANFP defined in Figure 1, a PSD mask (or set of PSD masks) is defined, and the dynamic PSD mask specification in Section C.3.2 of the ANFP is also defined which may be used alternatively at the NTP. Table 1 lists the 6 points of ANFP application and shows where in the ANFP specification the PSD mask(s) is specified.

Point of Application of the ANFP	Location in ANFP [1] for PSD Mask specification
MDF (at an MDF site/exchange) connected to metallic access network cables routed to an NTP via a SLCP.	Part A
SDF (at a sub-loop connection point)	Part B
NTP (at the customers' premises)	Part C
MDF Exchange Outlet (at an MDF site/exchange) connected to metallic access network cables routed directly to an NTP without a SLCP included in the routing and not sharing a cable sheath containing cables routed via a SLCP.	Part D
G-SDF Co-ordinated Group (as a, co-ordinated group of loops, sub-loop connection point)	Part E
NTP Co-ordinated Group (at the customer's premises) connected to metallic access network loops communicating with transmission equipment connected at the G-SDF	Part F
Note: Parts E and F are intended to be used in combination independent of Parts A to D. Part F shall only apply when connected to communicating with equipment operating in compliance with Part E.	

Table 1 - Interface Categories and PSD Mask Specification

When considering compliance of access transmission equipment to the ANFP, the proposed connection point (MDF, SDF, G-SDF, and NTP) needs to be considered and in the case of connection at the SDF and NTP, the SLCP CAL (Cabinet Assigned Loss) and ANFP line category respectively.

6 Guidance on the use of DSL in the BT Access Network

This section describes the various standardised access transmission systems currently available or being developed and considers whether they comply with the BT ANFP.

Note: xDSL systems that are non-compliant with the BT ANFP are highlighted and the details of their non-compliance described. It should be noted that there are mechanisms defined in the international standards to use the xDSL associated management system to permit the network operator to reduce or shape the transmit PSD of a system. This can be used to make an ANFP non-compliant system compliant.

The ANFP does not exclude specific systems; it excludes by implication: one may not install a system that does not conform to the appropriate masks at each of its ends. For example the ANFP would exclude the following standardised systems¹ from use on *any* BT access network line ('ultra short', 'extra short', 'short', 'medium' or 'long'):

- ISDN basic access using MMS43/4B3T line code - see Section 6.2.2.
- A 1-pair 2.3 Mbit/s HDSL system using 2B1Q or CAP
- ADSL over ISDN

¹ This list is of course not exhaustive.

- Reverse ADSL (i.e. with the high bandwidth implemented in the customer to exchange direction). This means that ADSL is precluded from use on private circuits.
- VDSL deployed at an MDF site.

6.1 Analogue Voice-band Frequency Systems

These systems comply with all Parts of the ANFP [1] and hence may be connected at all defined connection points to the BT access network.

6.2 ISDN Basic Access

6.2.1 2B1Q Line code

Basic-rate access transmission for the Integrated Services Digital Network (ISDN-BA) uses a 4-level Pulse Amplitude Modulation (PAM) line code known as 2B1Q. ISDN transceivers used in the UK employ Echo Cancellation techniques to enable full duplex transmission at 160kbit/s on a single unloaded telephony wire pair. The peak power spectral density of 2B1Q-based DSL systems is around 40 kHz with the first spectral null at 80kHz. ITU-T Recommendation G.961 and ETSI TS 102 080 V1.4.1 (2003-07) are the relevant international standards.

The ISDN payload is usually 2 x 'B' or Bearer channels at 64kbit/s each plus a 'D' or signalling channel at 16kbit/s. This gives the user access to 128kbit/s plus signalling (144kbit/s). An extra overhead of 16kbit/s is provided for an Embedded Operations Channel (EOC), intended for exchanging information between the LT (Line Terminal) and NT (e.g. link performance statistics). The EOC is not normally accessible to the user.

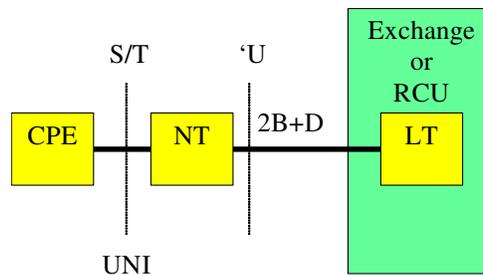


Figure 2 - Basic-rate ISDN-BA concept (DSL)

It is worth mentioning that DSL technology is also used as the transmission bearer technology for Digital Access Carrier (DAC) systems, which are used by BT to provide expedient 'analogue pair gain'. Pair gain systems convert a single wire-pair into two fully independent voice-band circuits and are used to provide normal analogue telephony service where there are insufficient copper pairs for a single metallic path per customer. Such systems are often used as expedient ways of providing service whilst more copper pairs are installed or to make maximum use of the existing infrastructure, obviating the need for more investment in providing D- or E-side pairs².

² D and E-side pairs refer to a metallic pair between the SDF and NTP and between the MDF and SDF respectively.

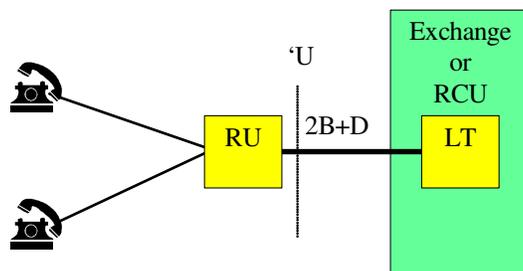


Figure 3 - Two channel digital pair gain (DACs) using ISDN-BA

2B1Q line code ISDN basic access systems are compliant to Parts A to D of the ANFP [1]

6.2.2 MMS43/4B3T Line code

There is a second type of ISDN system used in some parts of Europe (predominantly Germany) that uses an alternative line code called MMS43 or 4B3T. This system is defined in Annex B of ETSI TS 102 080 V1.3.2 (2000-05). In section B.12.4 of that document the PSD requirements are defined.

These requirements have been plotted in Figure 4 as the black graph, against the NTP-end requirements of the ANFP. It can be seen that a **system that is only just compliant with the standard violates the ANFP for all loop categories and therefore cannot be used on the BT access network.**

However it is noted that the requirements of the standard are loose; for example the penultimate paragraph of B.12.4.1 states "The result shall be less -120 dBm/Hz or at least more than 7 dB below the PSD..." This strongly suggests that it may be possible to procure MMS43-based ISDN systems with a vendor warranty of compliance to some or all categories of the ANFP.

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

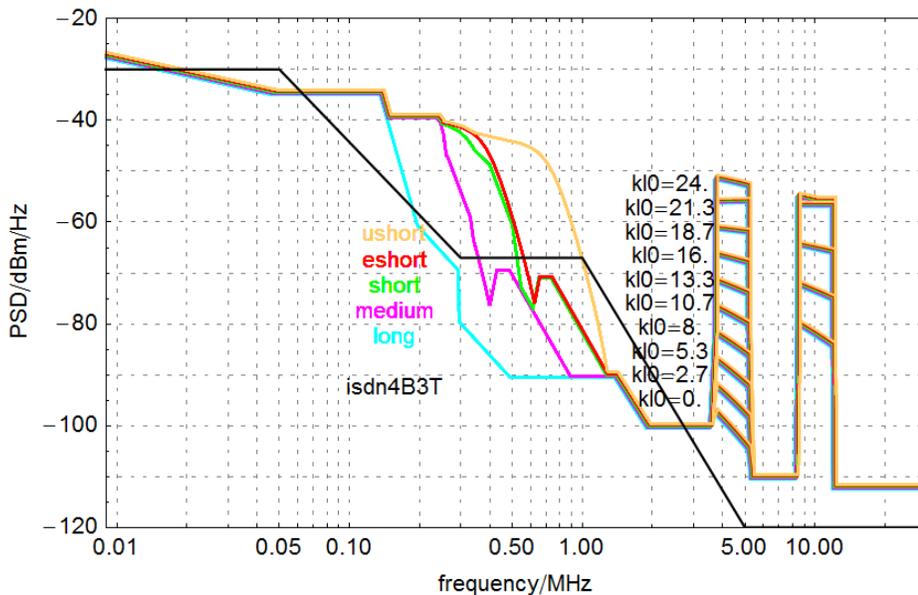


Figure 4 - MMS43/4B3T ISDN-BA versus ANFP Part C (NTP) PSD masks

6.3 HDSL

High bit-rate DSL modem standards evolved from earlier work on ISDN-BA. HDSL is a bi-directional symmetric transmission system that allows the transport of signals with a bit-rate of 1.544Mbit/s or 2.048Mbit/s on access network wire-pairs. HDSL uses the echo cancellation technique for the separation of the different directions of transmission. Two different options for the line code are available; Pulse Amplitude Modulation 2B1Q and the Carrierless Amplitude Modulation (CAP).

The 2B1Q HDSL system for 2.048Mbit/s caters for both duplex transmission on a single pair and parallel transmission on two or three pairs. This allows for the distribution of the data to several pairs and for the reduction of the symbol rate to increase the line length or transmission reach. CAP is defined for one or two pairs only and the 1.544Mbit/s 2B1Q for two pairs only. DSL bandwidth therefore increased (compared to ISDN-BA) to around 4-500kHz with the advent of HDSL.

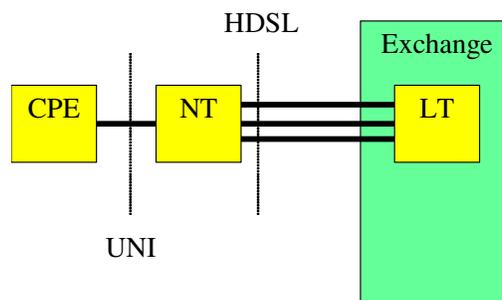


Figure 5 - High bit-rate DSL concept (HDSL)

ANSI T1E1.4 standardised HDSL in order to deliver 1.544Mbit/s (DS1) digital access using two wire-pairs, each carrying 784kbit/s. A framer/deframer was specified in order to separate the incoming data into two streams and recombine them at the receiver. This type of system has been very successful in North America.

In Europe, ETSI built on the good foundation work and initially adopted and standardised the 2B1Q 784kbit/s HDSL for providing structured and unstructured 2.048Mbit/s access using three wire-pairs. Subsequently, with improvements in HDSL technology, a 2-pair variant was standardised by ETSI followed by a 1-pair variant, each delivering 2.048Mbit/s over progressively shorter loops. ETSI also specified a Carrierless Amplitude/Phase variant for operation over one and two wire-pairs. This is in contrast to ANSI who only standardised the use of the 2B1Q line code for 2-pair HDSL delivering 1.544Mbit/s.

It is worth noting that ETSI has also specified HDSL for use in SDH applications where VC-12 or TU-12 can be transported in a 2.3 Mbit/s payload. However, there are spectral compatibility problems (interference to ADSL) with single pair HDSL systems running at such high bit-rates, which preclude their use on the BT network. This is because the Near end Crosstalk (NEXT) from single pair HDSL is very damaging to a Far end Crosstalk (FEXT) limited ADSL system.

The ITU-T also endorsed the use of HDSL via the G.991.1 standard. This Recommendation merges both the ANSI (TR No. 28) and ETSI TS 101 135 V1.5.3 (2000-09) specifications into a single standard.

The standardised HDSL systems listed in Table 2 are compliant with the ANFP when connected at the MDF and NTP.

ANFP Part C		
Ultra Short, Extra Short and Short Lines	Medium Line	Long Line
HDSL (2 pair E1) – 2B1Q	HDSL (3 pair E1) – 2B1Q	-
HDSL (2 pair E1 - 1168 kbit/s) - CAP	HDSL (2 Pair E1 - 1168 kbit/s) - CAP	-

Table 2 - HDSL systems allowed under the ANFP

6.4 SHDSL³

The ITU-T SG 15/4 completed work on G.SHDSL (G.991.2) in 2001, and a revised version was published in 2003 (see section 6.5). The ITU standard for Single-pair High-speed Digital Subscriber Line (SHDSL) Transceivers Recommendation G.991.2 describes a symmetric transmission method for data transport in access networks. SHDSL is designed to transport rate-adaptive symmetrical data across a single copper pair at data rates from 192 kbps to 2.3 Mbps or 384 kbps to 4.6 Mbps over two pairs. Using a Trellis Coded Pulse Amplitude Modulation (TC-PAM) line code G.991.2 modems can be configured to operate at longer ranges than most of the existing DSL technologies, while maintaining spectral compatibility with all other DSL technologies when regional spectral deployment guidelines are followed. Table 3 lists the maximum G.SHDSL rates that are compliant to the ANFP. The downstream PSD for the fastest G.SHDSL speed versus the ANFP exchange mask is shown in Figure 6.

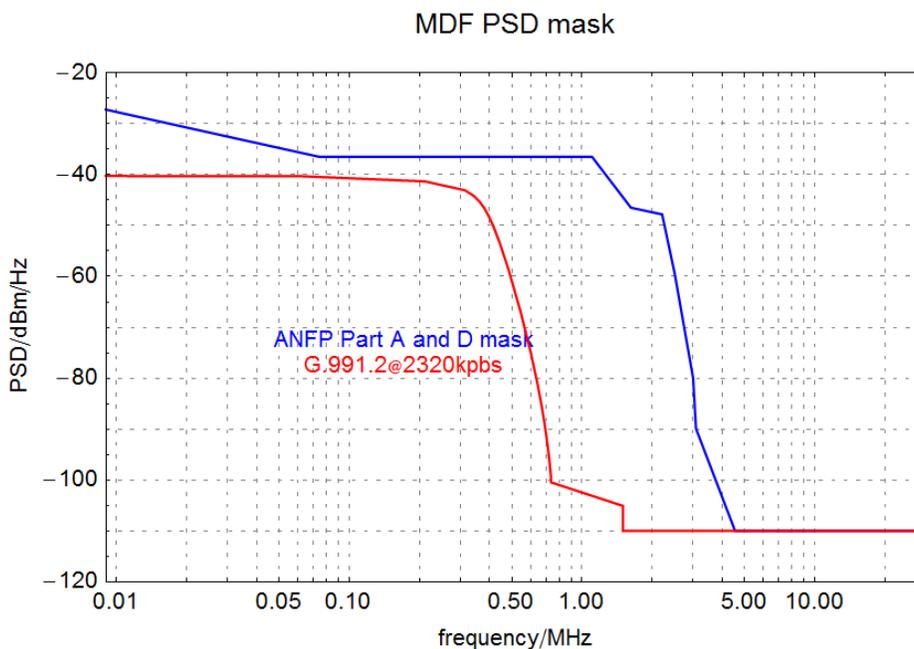


Figure 6 - G.991.2 running at 2320kbps versus ANFP Part A and Part D PSD Masks

³ SHDSL is often referred to as SDSL (Symmetric DSL). This should not be confused with the USA use of the term 'SDSL' which refers to DSL systems similar to HDSL.

ANFP Loop Category (nominal electrical length)	Maximum SHDSL Line Rate ⁴
Ultra Short (typically $\leq 11\text{dB}$)	2320 kbps
Extra Short (typically $>11\text{dB}$, $\leq 21\text{dB}$)	2320 kbps
Short (typically $>21\text{dB}$, $\leq 26\text{dB}$)	2056 kbps
Medium (typically $>26\text{dB}$, $\leq 29\text{dB}$)	1505 kbps
Long (typically $>29\text{dB}$)	784 kbps

Table 3 - Maximum SHDSL line rates allowed under the ANFP

Figure 7 to Figure 10 below show the compliant G.SHDSL PSD masks for the different ANFP loop categories.

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

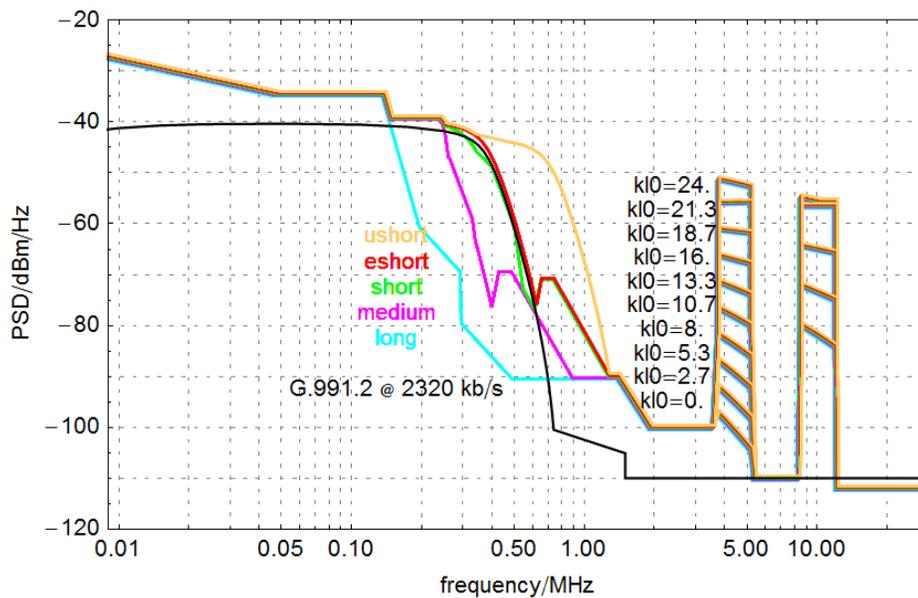


Figure 7 - G.991.2 running at 2320kbps versus ANFP Part C (All Masks)

Figure 7 shows that SHDSL running at 2320 kbps is only compliant on Ultra Short and Extra Short lines.

⁴ The line rate includes the 8 kbps overhead for framing and signalling. Hence the equivalent user rate is 8 kbps less.

NTP ushort, eshort, short, medium and long PSD masks for various values of kI0

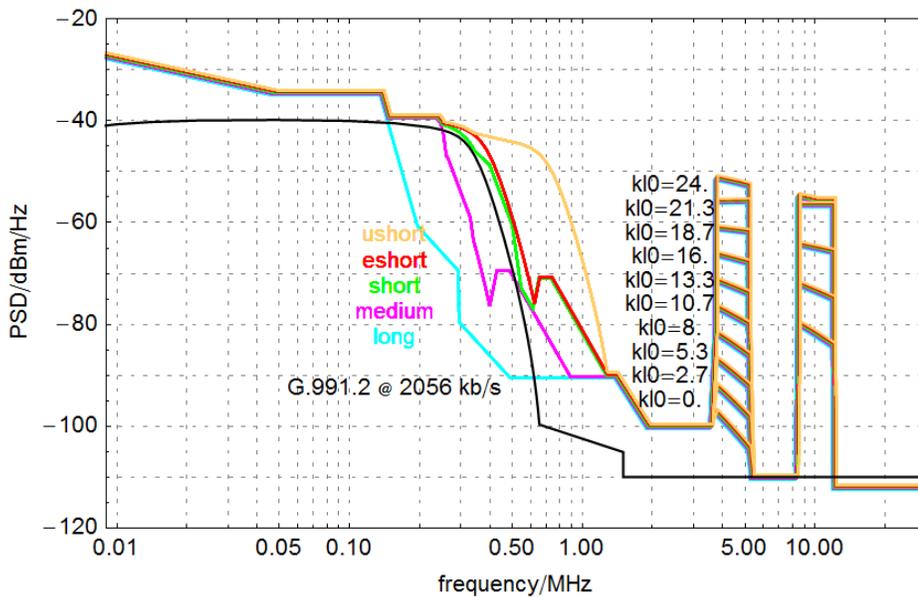


Figure 8 - G.991.2 running at 2056kbps meets ANFP Part C (Upstream Short mask)

NTP ushort, eshort, short, medium and long PSD masks for various values of kI0

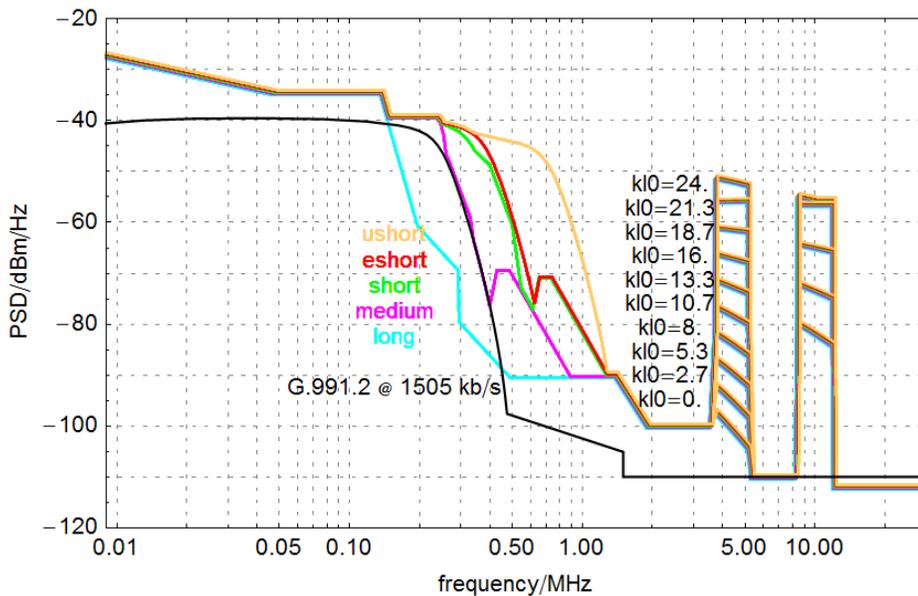


Figure 9 - G.991.2 running at 1505kbps meets ANFP Part C (Upstream Medium mask)

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

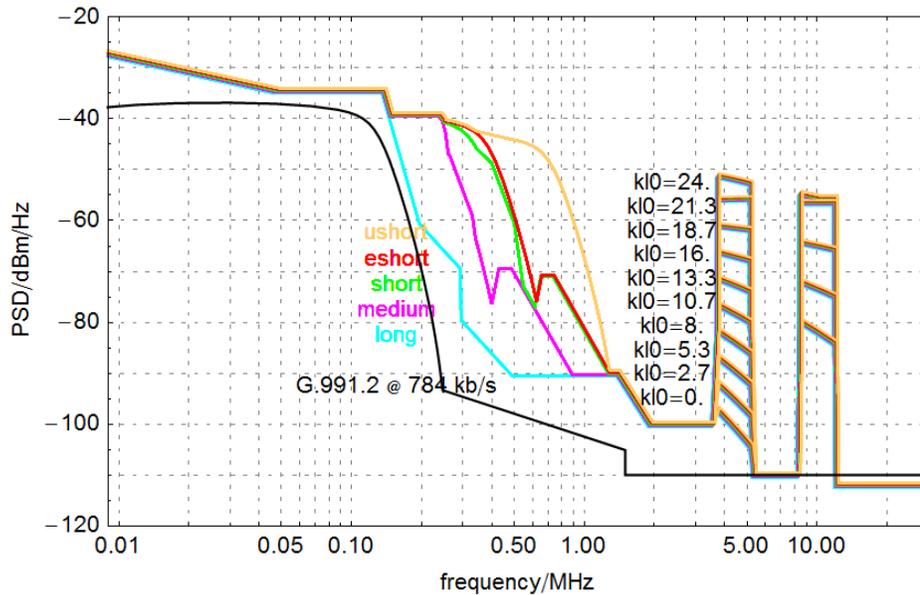


Figure 10 - G.991.2 running at 784kbps meets ANFP Part C (Upstream Long mask)

6.5 Enhanced SHDSL (SHDSL.bis)

An enhanced version of SHDSL commonly referred to as G.SHDSL.bis (G.991.2-2003), was released in 2003. Optional extensions which are more spectrally dense by a factor of 4/3 than the non-enhanced version support rates up to 5696 kbit/s are described in Annex F and Annex G⁵. Annex F describes the extensions for region 1 (North America) whilst Annex G describes the extensions for region 2 (Europe). Since SHDSL.bis has a symmetrical PSD, the limiting masks are the upstream ones, these being more restrictive than the downstream mask (as far as SHDSL is concerned). Figure 11 shows the maximum SHDSL.bis rate PSD compared to the ANFP downstream mask. It is also worth mentioning that the EFM (Ethernet in the First Mile) standard (IEEE 802.3ah) uses SHDSL.bis line coding for the long reach PHY (EFMC LR).

⁵ Annex G was introduced in G.991.2 amendment 2 (02/2005). ETSI defined a similar Annex E in TS 101 524 rev 1.3.1 (02/2005).

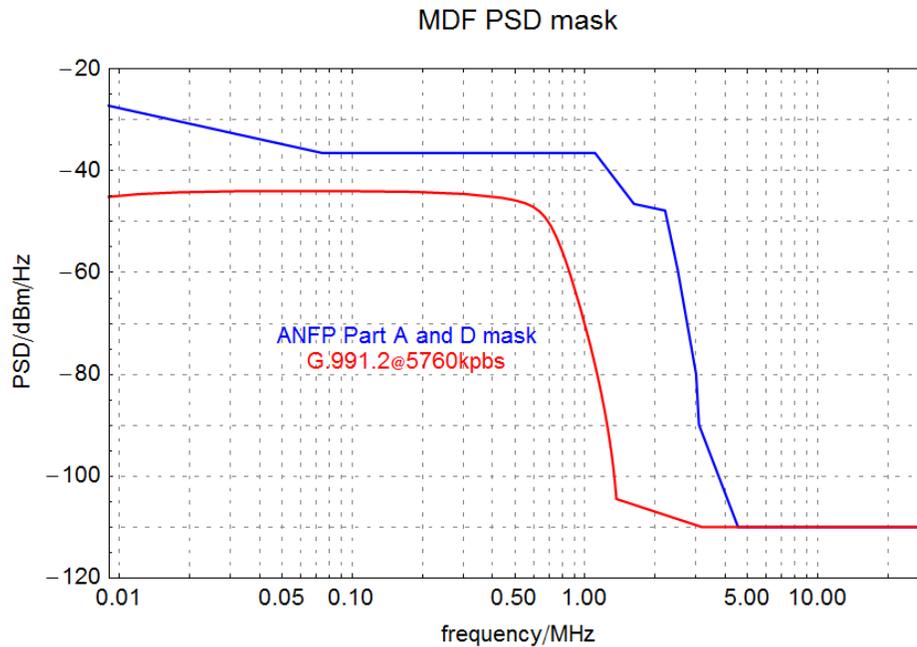


Figure 11 - G.991.2.bis running at 5696kbps versus ANFP Part A and Part D PSD Masks

ANFP Loop Category (nominal electrical length)	Maximum SHDSL.bis Line Rate for TCPAM-16	Maximum SHDSL.bis Line Rate for TCPAM-32 ⁶
Ultra Short (typically ≤ 11 dB)	3840 kbps ⁷	5696 kbps
Extra Short (typically > 11 dB, ≤ 21 dB)	2320 kbps ⁸	3088 kbps
Short (typically > 21 dB, ≤ 26 dB)	2056 kbps	2736 kbps
Medium (typically > 26 dB, ≤ 29 dB)	1504 kbps	2000 kbps
Long (typically > 29 dB)	784 kbps	1040 kbps

Table 4 - Maximum SHDSL.bis line rates allowed under the ANFP

Table 4 lists the maximum line rates (this includes the 8 kbps overhead for framing and signalling and hence the user rates are 8 kbps lower) that are allowed for each loop category under the ANFP. Note that these are maximums and there is no guarantee that these rates will be achieved on the different loop categories. Figure 12 to Figure 16 below show the SHDSL.bis PSD masks for the loop categories Ultra Short, Extra Short, Short, Medium and Long respectively.

⁶ The maximum SHDSL.bis allowed line rate with TC-PAM 32 line code. The line rate includes the 8 kbps overhead for framing and signalling. Hence the equivalent user rate is 8 kbps less.

⁷ This rate does not fully exploit the PSD permitted by the Ultra Short category, but is the maximum rate for this constellation described in the eSHDSL Annex of the standard.

⁸ The greyed out rates do not need eSHDSL to achieve them, as they can be reached by conventional SHDSL.

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

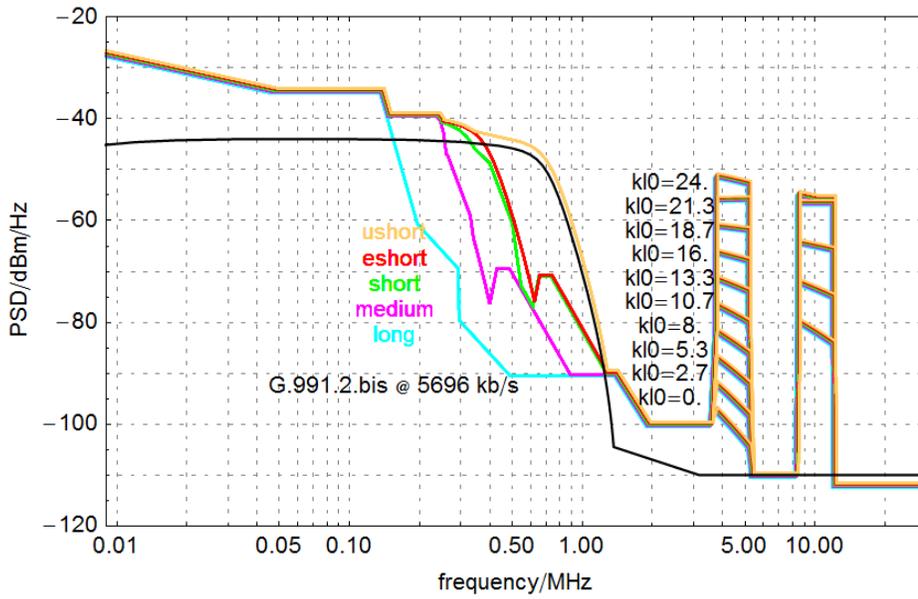


Figure 12 - G.991.2.bis at 5696 kb/s meets ANFP Part C Upstream Ultra Short Mask

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

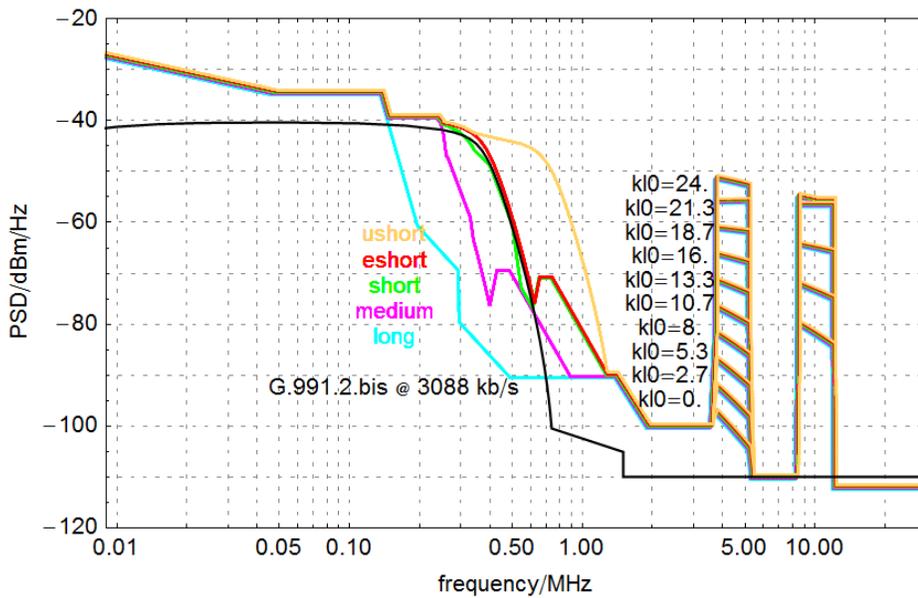


Figure 13 - G.991.2.bis at 3088kb/s meets ANFP Part C Upstream Extra Short Mask

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

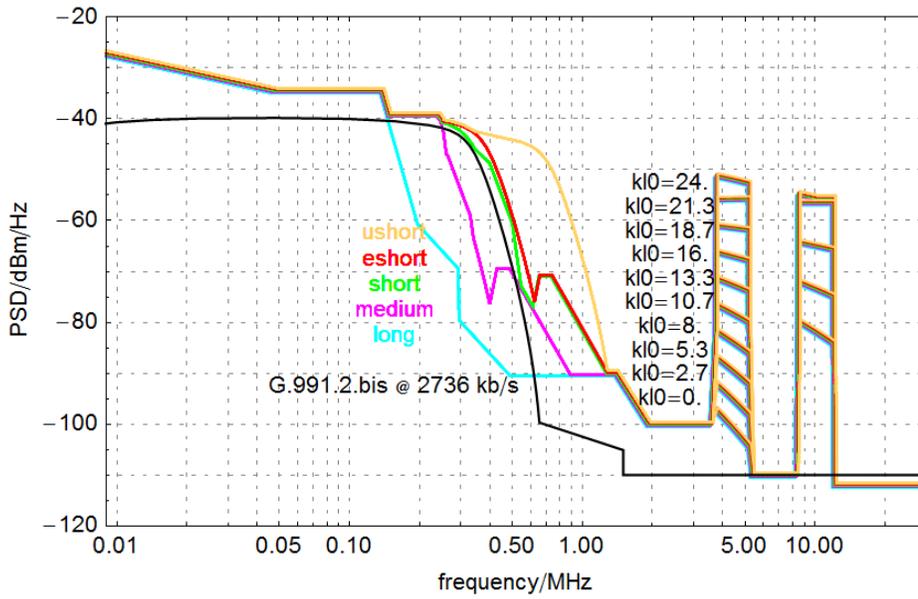


Figure 14 - G.991.2.bis at 2736kbps meets ANFP Part C Upstream Short Mask

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

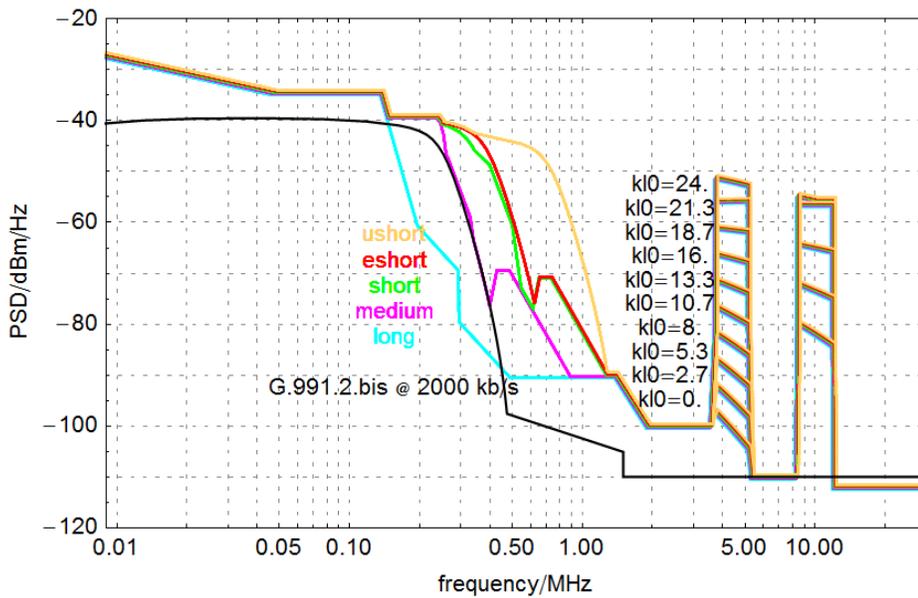


Figure 15 - G.991.2.bis at 2000kbps meets ANFP Part C Upstream Medium Mask

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

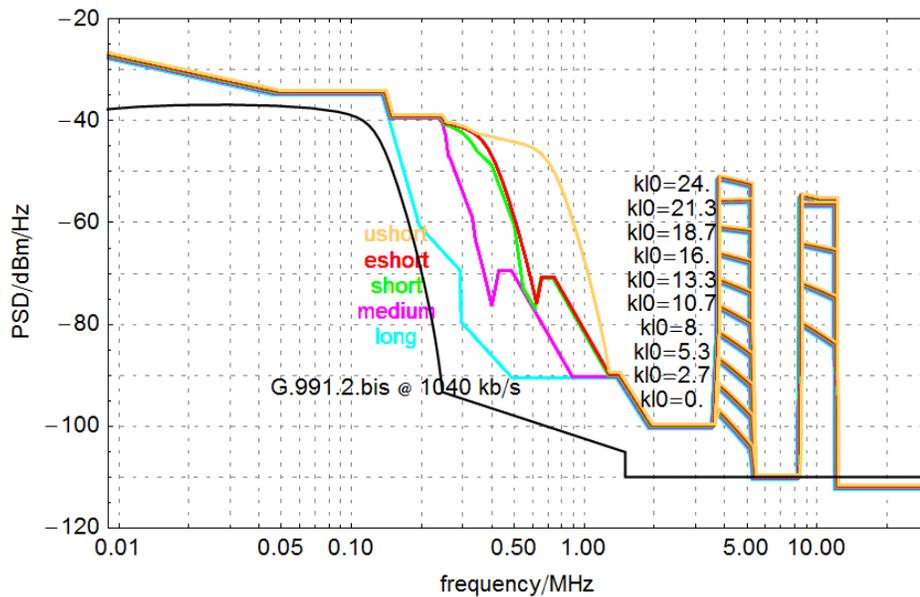


Figure 16 - G.991.2.bis at 1040kbps meets ANFP Part C (All masks)

6.6 ADSL and ADSL2

ITU-T Recommendations G.992.1 (G.dmt) and G.992.2 specify full-rate and splitterless ADSL respectively. These standards include Annexes that define the use of ADSL in various environments throughout the world (see Table 5). Since these two standards were ratified in 1999, the ITU-T has added enhancements to produce the ADSL2 recommendations G.992.3 and G.992.4 (for full-rate and splitterless respectively). Both ADSL and ADSL2 use the same frequency spectrum and their compliance with the ANFP can be considered together. The ITU standards incorporate ETSI TS 101 388 V1.3.1 (2002-05).

ADSL2plus (or ADSL2+) is defined in ITU-T Recommendation G.992.5 published in 2003. It uses a frequency spectrum up to 2.2 MHz compared with 1.1 MHz for ADSL/ADSL2 and hence its compliance with the ANFP needs to be considered separately from ADSL/ADSL2 - see Section 6.9.

ADSL standards include Annexes that specify ADSL operation for particular applications and regions around the world. Generally, the Annexes specify subcarriers (or tones) and their associated transmission power levels used for upstream and downstream transmission. The naming convention is such that Annexes to the DMT-based ITU-T DSL standards use the same identifying letter (e.g. A, B, C, etc.) across each of the recommendations to designate the same area of concern and similar use of the DMT subcarriers.

Annex	1-5	6-31	32-64	65-255	256-512*	ADSL G.992.1	ADSL2 G.992.3	ADSL2+ G.992.5
A	POTS	UP	DOWN	DOWN	DOWN	YES	YES	YES
B	ISDN	ISDN	UP	DOWN	DOWN	YES	YES	YES
C	TCM ISDN	UP	DOWN	DOWN	DOWN	YES	YES	YES
I	UP	UP	DOWN	DOWN	DOWN	N/A	YES	YES
J	UP	UP	UP	DOWN	DOWN	N/A	YES	YES
L	POTS	UP**	DOWN**	DOWN	DOWN	N/A	YES	NO
M	POTS	UP	UP	DOWN	DOWN	N/A	YES	YES

Use of tones applies to the non-overlapped PSD masks only. Equivalent frequencies can be determined by multiplying the tone number by the tone spacing (i.e. 4.3125kHz)

* ADSL2+ only

** Not all tones are used

N/A Not Applicable

Table 5 - Use of Tones in ADSL Standard Annexes

6.6.1 ADSL/ADSL2 compliance to the ANFP

Parts A, B, C and D given in the sub-section headings below, refer to the respective Part of the ANFP [1].

6.6.1.1 Part A: MDF requirements and Part D: MDF EO requirements

Table 6 is a summary of the compliance of ADSL and ADSL2 equipment with the ANFP Part A and Part D, where tones shown in **red** indicate non-compliance.

Annex	1-5	6-31	32-64	65-255
A	POTS		DOWN	DOWN
B	ISDN	ISDN		DOWN
C	TCM ISDN		DOWN	DOWN
I			DOWN	DOWN
J				DOWN
L	POTS		DOWN	DOWN
M	POTS			DOWN

Table 6 - ADSL2 v ANFP Parts A and D

The cases where tones used are not supported by the ANFP are demonstrated in Figure 17 below.

Annex L

The ATU-C downstream transmit spectral mask for Annex L is not supported by the ANFP without downstream spectrum shaping. See Figure 17 and also Section 6.7. (The figure uses the values from ITU-T G.992.3 section L.1.3 "ATU-C downstream transmit spectral mask for non-overlapped spectrum reach-extended operation".)

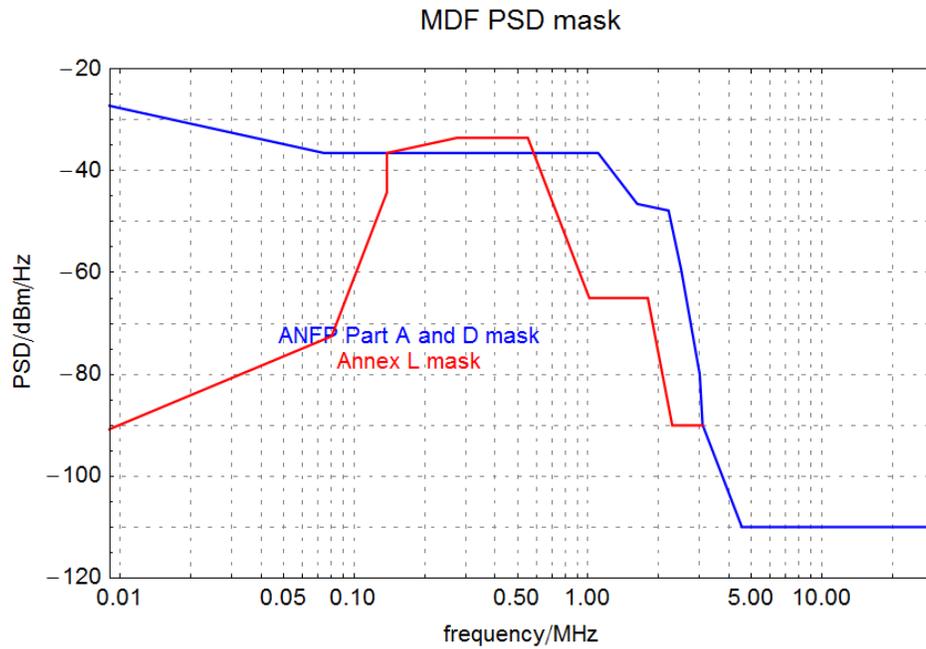


Figure 17 - ANFP Parts A and D PSD mask and ADSL2 Annex L downstream peak PSD mask.

6.6.1.2 Part B: Cabinet requirements

Table 7 is a summary of the compliance of ADSL and ADSL2 equipment with the ANFP Part B, where tones shown in *red* indicate non-compliance.

Annex	1-5	6-31	32-64	65-255
A	POTS		<i>DOWN¹</i>	<i>DOWN¹</i>
B	ISDN	ISDN		<i>DOWN¹</i>
C	<i>TCM</i> <i>ISDN</i>		<i>DOWN¹</i>	<i>DOWN¹</i>
I			<i>DOWN¹</i>	<i>DOWN¹</i>
J				<i>DOWN¹</i>
L	POTS		<i>DOWN²</i>	<i>DOWN²</i>
M	POTS			<i>DOWN¹</i>
Note 1: Annex A, B, I, J and M equipment is compliant downstream for CAL 0 and 72 cabinets only. Note 2: Annex L equipment is compliant downstream for CAL 72 cabinets only.				

Table 7 - ADSL2 v ANFP Part B

The cases where tones used are not supported by ANFP are demonstrated in Figure 18 below.

The ATU-C downstream transmit spectral mask for all Annex (A, B, I, J, L, and M) is in general not supported by the ANFP without downstream spectrum shaping although for the special case of CAL 0 and CAL 72, ADSL and ADSL2 equipment may be compliant. See Figure 18. (The figure uses a typical template based on the values from ITU-T G.992.3 section A.1.3 "ATU-C transmitter PSD mask for non-overlapped spectrum operation".)

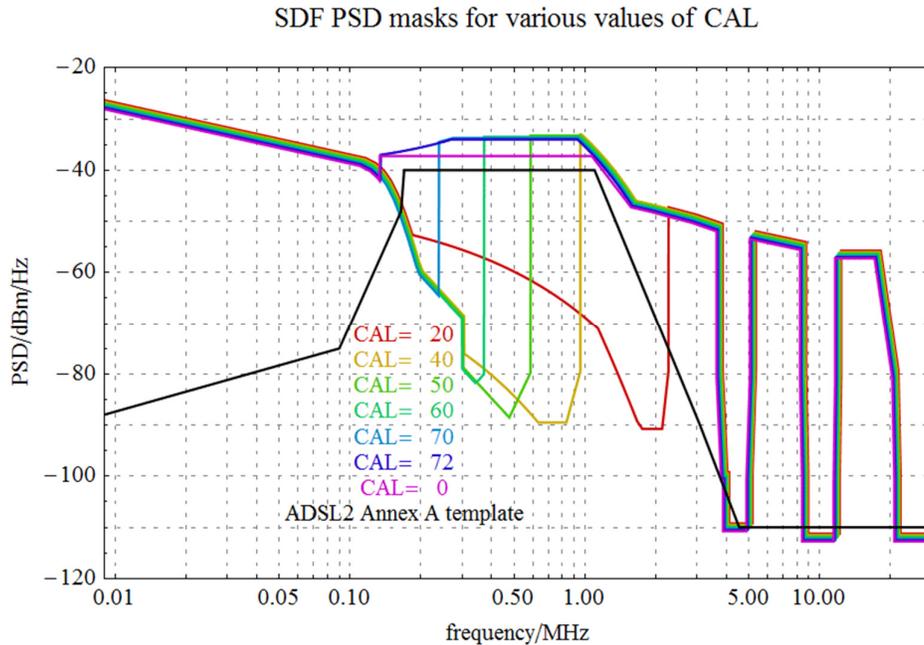


Figure 18 - ANFP Part B PSD mask and ADSL2 Annex A downstream PSD template.

6.6.1.3 Part C: Customer end requirements

Table 8 is a summary of the compliance of ADSL and ADSL2 equipment with the ANFP Part C, where tones shown in *red* indicate non-compliance.

Annex	1-5	6-31	32-64	65-255
A	POTS	UP		
B	ISDN	ISDN	<i>UP</i>	
C	<i>TCM</i> <i>ISDN</i>	UP		
I	UP	UP		
J	UP	UP	<i>UP</i>	
L	POTS	<i>UP**</i>		
M	POTS	UP	<i>UP</i>	

Table 8 - ADSL2 v ANFP Part C

The cases where tones used are not supported by ANFP are demonstrated in Figure 19 to Figure 23 below.

Annex B

The ATU-R upstream transmit spectral mask for Annex B is not supported by the ANFP without upstream spectrum shaping.

Example shown in Figure 19. (The figure uses the values from ITU-T G.992.3 section B.2.2 “ATU R upstream transmit spectral mask”.)

NTP ushort, eshort, short, medium and long PSD masks for various values of k_{l0}

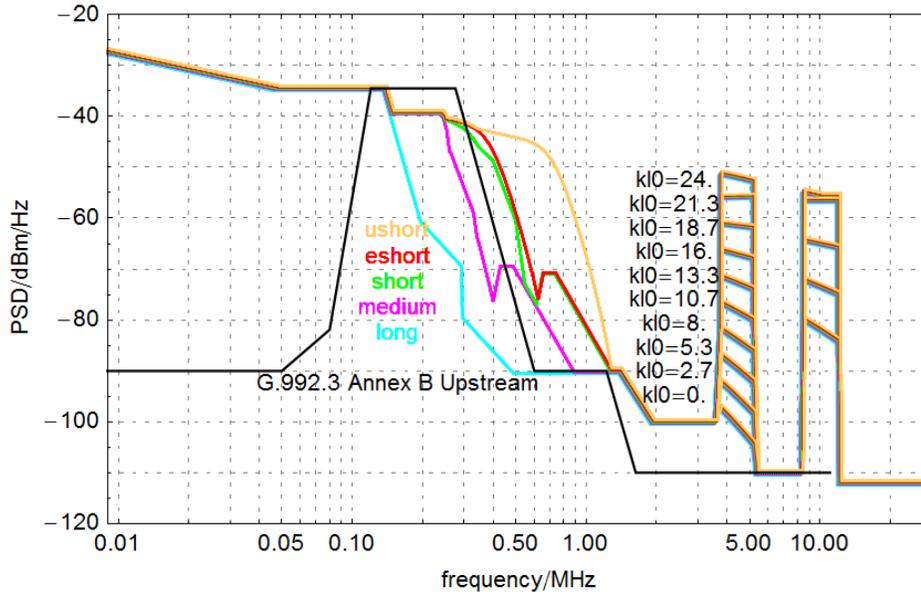


Figure 19 - ANFP Part C - long PSD mask and ADSL2 Annex B peak PSD.

Annex J

The ATU-R upstream transmit spectral mask for Annex J is not supported by the ANFP without upstream spectrum shaping.

Example shown in Figure 20. (The figure uses the values from ITU-T G.992.3 section J.2.2 “ATU R upstream transmit spectral mask”.)

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

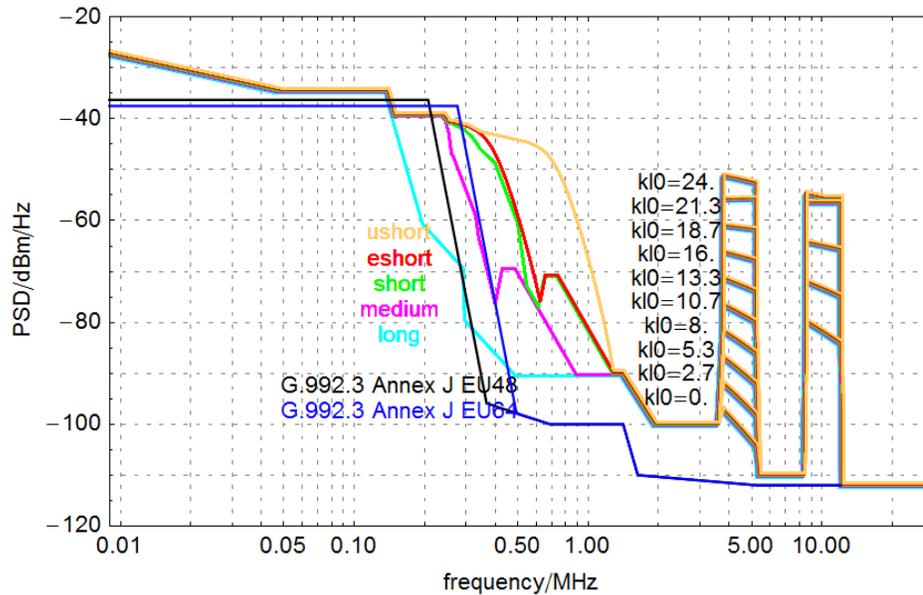


Figure 20 - ANFP Part C - long PSD mask and ADSL2 Annex J EU-48 and EU-64 peak PSD.

PSD shaping can be used to modify the PSD EU-64 in Annex J of G.992.3 to be compliant to the requirements of the ANFP for short distances. Figure 21 shows the simulation results⁹ on the impact on performance as a result of the PSD shaping. From this it can be concluded that the performance loss between EU-64 and ANFP compliant EU-64 is not significant. Data rates of 2 Mbps are possible up to around 1.8 km with interference from 24 self-disturber + 24 SHDSL at 2.3 Mbps.

⁹ Nominal PSDs are used in the simulation (i.e., 3.5 dB less than max PSD)

Used downstream tones: 65-255; Used upstream tones: 2-64

Coding gain: 5 dB; SNR margin: 6 dB

SNRGAP: 9.75; Used bits/tone: 1-15

Background noise: -140 dBm/Hz; Simulated test loop: ETSI Loop # 1 (0.4 mm)

The simplified NEXT model was used. The FSAN summation method was used to combine different types of disturbers.

The simulated scenario consisted of:

1. 49 ADSL Annex J as self-disturber
2. 24 Annex J + 24 SHDSL at 2.3 Mbit/s

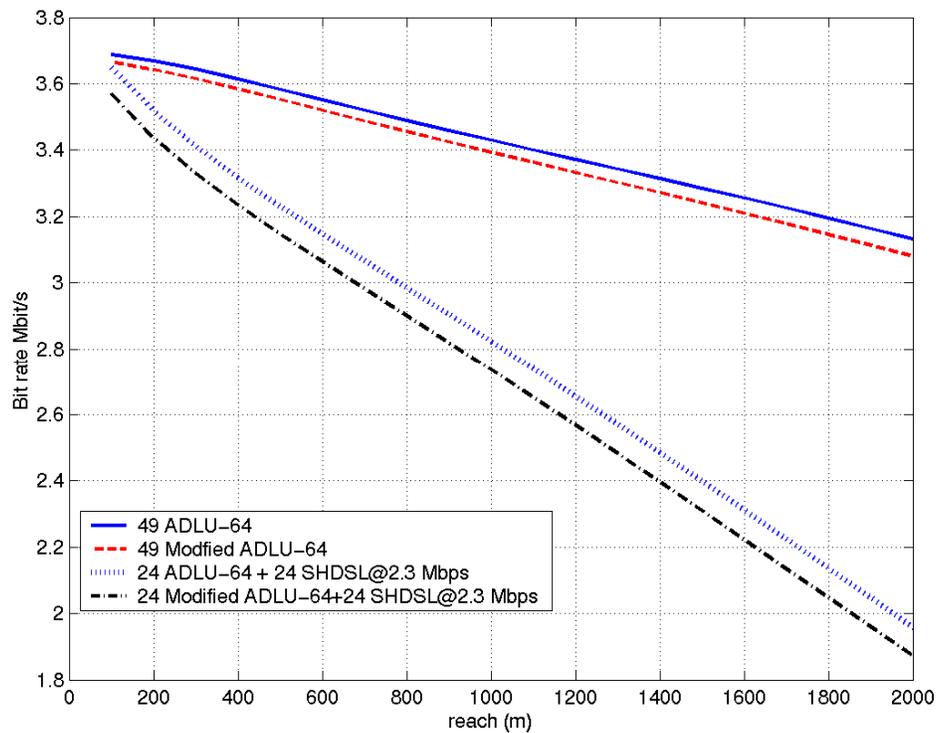


Figure 21 - ADSL upstream bit rate with 49 self-disturbers and with 24 ADSL + 24 SHDSL at 2.3 Mbit/s.

Annex L

The ATU-R upstream transmit spectral mask for Annex L is not supported by the ANFP without upstream spectrum shaping.

Example shown in Figure 22. (The figure uses the values from ITU-T G.992.3 section L.2.2 “ATU-R upstream transmit spectral mask 1 for reach-extended operation” and section L.2.3 “ATU-R upstream transmit spectral mask 2 for reach-extended operation”.)

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

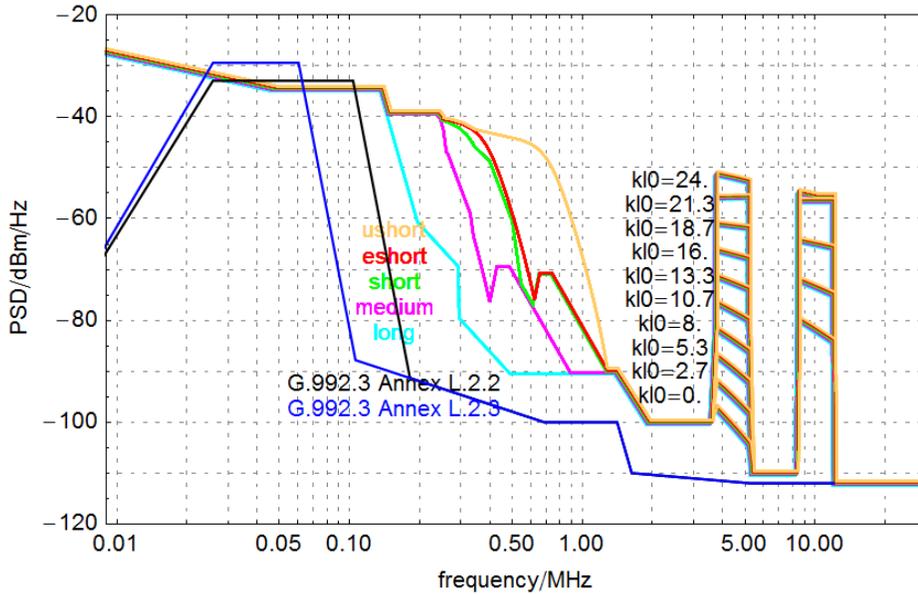


Figure 22 - ANFP Part C - long PSD mask and ADSL2 Annex L.

Annex M

The ATU-R upstream transmit spectral mask for Annex M is not supported by the ANFP without upstream spectrum shaping - see also Section 6.8. Example shown in Figure 23. (The figure uses the values from ITU-T G.992.3 and G.992.5 section M.2.2.1 “Passband PSD and response”)

NTP ushort, eshort, short, medium and long PSD masks for various values of k10

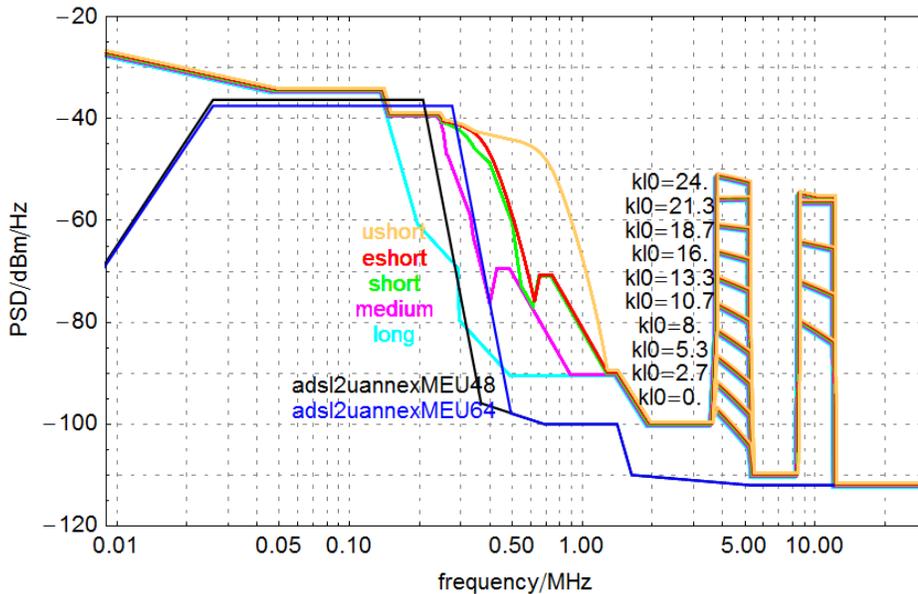


Figure 23 - ANFP Part C - short PSD mask using k10=0 and ADSL2 Annex M EU-48 and EU-64 peak PSD mask.

6.7 READSL2 (Annex L)

Annex L of the ITU ADSL standards, also known as READSL2, extends the reach of ADSL2 at low bit-rates through transmit PSD shaping. The upstream tones 6-14 can have a PSD boosted beyond the normal ADSL2 level of -38 dBm/Hz to a higher level of -32.9 dBm/Hz. Upstream tones 14-24 are boosted to -36.4 dBm/Hz. In the downstream direction, the PSD rises from the normal -40 dBm/Hz level at tone 32 to -37 dBm/Hz up to tone 128. Frequencies beyond tone 128 (552 kHz) are not used. This technique can extend the reach of ADSL or offer higher downstream rates on long lines. It is spectrally compatible with ADSL2 and being a derivative of the normal DMT ADSL standards it can be combined with ADSL and ADSL2 on the same line card. The standard facilitates auto-mode detection based on a handshake protocol that means that the DMT ADSL chips can automatically detect support of READSL2 to select the required operation mode. The down side of READSL2 is that the downstream max rate is limited to around 5.5 Mbit/s (and upstream rate limited to ~ 800 kbit/s).

READSL2 is not supported by the ANFP - see section 6.6.1.1 and 6.6.1.3.

6.8 Extended Upstream ADSL (Annex M)

Annex M of the ITU ADSL standards boosts the upstream data rate to around 3 Mbit/s. It achieves this shifting the split of frequencies between ADSL upstream and downstream bands to a higher frequency. This results in a larger upstream band at the expense of a narrower downstream band. Overall it uses a similar aggregate upstream power to ADSL2. Annex M can be combined with ADSL2 or ADSL2plus. Whilst ADSL Annex M can provide higher upstream rates for services such as high-quality videoconferencing, it is not spectrally compatible with ADSL over POTS (Annex A), which is widely deployed on the BT network. This is due to the crosstalk that would result in mutual interference because the Annex M upstream band overlaps with the Annex A downstream band (DMT tones 32-63).

However, with spectrum shaping Annex M ADSL can be made to be compliant with the ANFP - see section 6.6.1.3 and also the Note in Section 6.

6.9 ADSL2 Plus

ADSL2plus (also written as ADSL2+) reached consent at the ITU in January 2003, joining the ADSL2 standards family as G.992.5. The ADSL2plus recommendation doubles the downstream bandwidth, thereby increasing the downstream data rate on shorter telephone lines. While ADSL and ADSL2 standards specify a downstream frequency band up to 1.1 MHz, ADSL2+ specifies a downstream frequency up to 2.2 MHz (Figure 24). The result is a significant increase in downstream data rates on shorter phone lines. ADSL2+ upstream data rate is about 1 Mbps, depending on loop conditions.

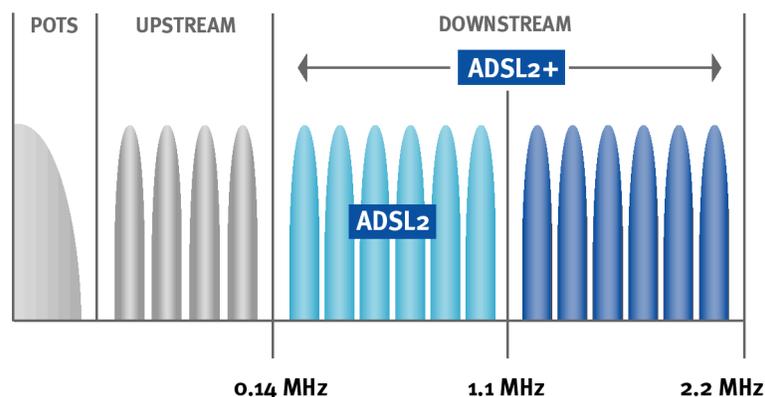


Figure 24 - ADSL2plus doubles the bandwidth used to carry downstream data

6.9.1 ADSL2+ Compliance with ANFP

Parts A, B, C and D given in the sub-section headings below, refer to the respective Part of the ANFP [1].

6.9.1.1 Part A: MDF Requirements and Part D: MDF EO Requirements

Table 9 is a summary of the compliance of ADSL2+ equipment with the ANFP Part A and Part D. All ADSL2+ tones are compliant (hence no tones are shown in *red* indicating non-compliance).

Annex	1-5	6-31	32-64	65-255	256-512
A	POTS		DOWN	DOWN	DOWN
B	ISDN	ISDN		DOWN	DOWN
C	TCM ISDN		DOWN	DOWN	DOWN
I			DOWN	DOWN	DOWN
J				DOWN	DOWN
L	N/A	N/A	N/A	N/A	N/A
M	POTS			DOWN	DOWN

Table 9 - ADSL2+ v ANFP Part A and Part D

6.9.1.2 Part B: Cabinet Requirements

Table 10 is a summary of the compliance of ADSL2+ equipment with the ANFP Part B, where tones shown in *red* indicate non-compliance.

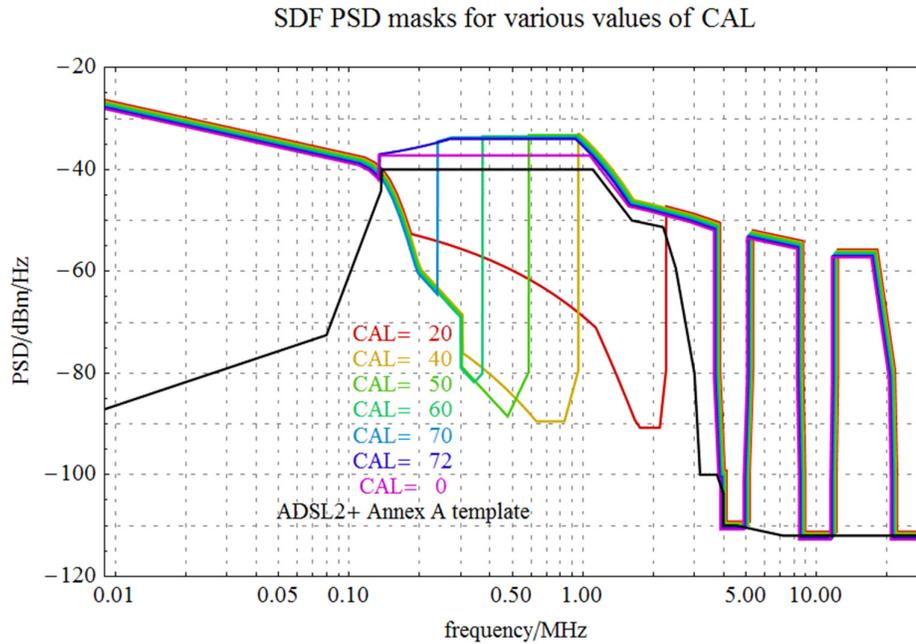
Annex	1-5	6-31	32-64	65-255	256-512
A	POTS		<i>DOWN¹</i>	<i>DOWN¹</i>	<i>DOWN¹</i>
B	ISDN	ISDN		<i>DOWN¹</i>	<i>DOWN¹</i>
C	TCM ISDN		<i>DOWN¹</i>	<i>DOWN¹</i>	<i>DOWN¹</i>
I			<i>DOWN¹</i>	<i>DOWN¹</i>	<i>DOWN¹</i>
J				<i>DOWN¹</i>	<i>DOWN¹</i>
L	N/A	N/A	N/A	N/A	N/A
M	POTS			<i>DOWN¹</i>	<i>DOWN¹</i>

Note 1 : Annex A, B, I, J and M equipment is compliant downstream for CAL 0 and 72 cabinets only

Table 10 - ADSL2+ v ANFP Part B

The cases where tones used are not supported by ANFP are demonstrated in Figure 25 below.

The ATU-C downstream transmit spectral mask for all Annex (A, B, I, J, and M) is in general not supported by the ANFP without downstream spectrum shaping although for the special case of CAL 0 and CAL 72, ADSL2+ equipment may be compliant. ADSL2+ has an operator configurable spectrum shaping method which may be configured to make it compliant. See Figure 25. (The figure uses a typical template based on the values from ITU-T G.992.5 section A.1.3 "ATU-C transmitter PSD mask for non-overlapped spectrum operation".)



**Figure 25 - ANFP Part B PSD mask and
ADSL2+ Annex A downstream PSD template.**

6.9.1.3 Part C: Customer End Requirements

Table 11 is a summary of the compliance of ADSL2+ equipment with the ANFP Part C, where tones shown in *red* indicate non-compliance.

Annex	1-5	6-31	32-64	65-255	256-512
A	POTS	UP			
B	ISDN	ISDN	<i>UP</i>		
C	TCM ISDN	UP			
I	UP	UP			
J	UP	UP	<i>UP</i>		
L	N/A	N/A	N/A	N/A	N/A
M	POTS	UP	<i>UP</i>		

Table 11 - ADSL2+ v ANFP Part C

For examples see section 6.6 ADSL and ADSL2.

6.10 VDSL1

Very high speed Digital Subscriber Line, or VDSL1 (G.993.1), can operate in either a symmetric or an asymmetric mode and provides up to 52 Mbps of total data capacity over voice on a single twisted-pair copper loop. The VDSL1 specification approved by the ITU in 2004 is based on the T1E1 T1.424-2004 specification and the ETSI specifications TS 101 270-1 V1.3.1 (2003-07) and TS 101 270-2 V1.2.1 (2003-07), which provide the European requirements, and transceiver specification. VDSL1 is twice as fast as ADSL2plus and nearly ten times faster than ADSL. The trade-off for increased speed is loop length: VDSL1 has a shorter reach in the loop.

Like other DSL technologies, VDSL1 uses the higher-frequency spectrum available over standard copper above the frequencies used for lifeline POTS and ISDN services. This is commonly referred to as data- and video-over-voice technology. This technology enables telecommunication operators to utilize existing copper infrastructure for the delivery of broadband services over the same physical plant. The VDSL1 spectrum is specified to range from 200 kHz to 12 MHz. Actual spectral allocation varies based on line rates and whether or not asymmetric or symmetric rates are being used. The baseband for lifeline POTS and ISDN service is preserved by using passive filters commonly known as splitters.

There is one main band plan plus one alternate band plan that define what frequencies shall be used for upstream and downstream transmission as shown in Figure 26 below.

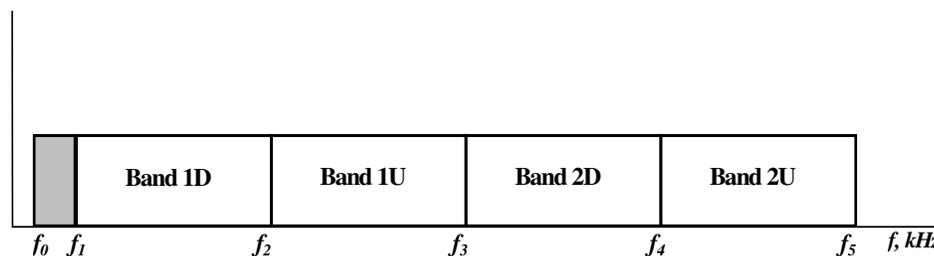


Figure 26 - Illustrative VDSL1 Band Allocation

Band Transition Frequencies (kHz)	f_0	f_1	f_2	f_3	f_4	f_5
VDSL1 bands	25	138	3 000	5 100	7 050	12 000
Optional regional-specific bands	25	138	3 750	5 200	8 500	12 000

Table 12: Band transition frequencies

NOTE 1: Use of frequencies above f_5 is not defined.

NOTE 2: Use of frequencies between f_0 and f_1 in the upstream direction is optional.

NOTE 3: The VDSL1 bands correspond to the frequency plan formerly named 997 and the optional regional-specific bands correspond to the frequency plan formerly named 998.

The band allocation for VDSL1 is shown in Figure 27.

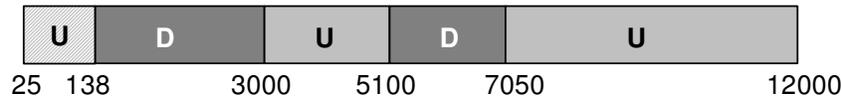


Figure 27 - VDSL1 Band Allocation

Optionally, modems may use the band allocation shown in Figure 28 to satisfy alternative regional requirements.

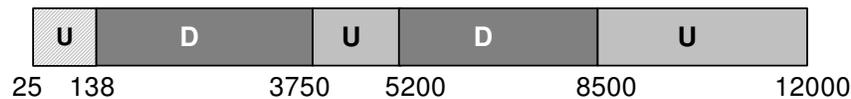


Figure 28 - Optional regional-specific VDSL1 Band Allocation

There are many different deployment scenarios discussed in the standards and each one has a unique PSD mask. The compatibility of systems compliant with these masks is discussed in the next section. Note that on longer loops no useful capacity is available in the upper downstream and upstream bands so the modem may choose not to transmit any energy in them.

The modem at the customer premises must implement an Upstream Power Back Off (UPBO) algorithm which is used to reduce the transmit power on short loops. The modem estimates the loop attenuation (electrical length) and derives the parameter kl_0 which is used to define the upper limit for the transmit PSD.

The general form of the equation to calculate the PSD at any in-band frequency is:-

$$TxPSD(kl_0, f) = -a - b\sqrt{f} + kl_0\sqrt{f} \quad \text{in dB}$$

Where the constants appropriate for use with the ANFP are $a = 60$ and $b = 17$. Note that kl_0 is limited to the range 0 to 17.

The network operator can also use its management system to impose a maximum upstream PSD limit on the modem.

6.10.1 VDSL1 Compliance with ANFP

The ANFP prohibits the use of VDSL1 from the exchange, even on short line lengths that have no sub-loops.

VDSL1 cannot normally comply with the ANFP Part B requirement to shape the downstream PSD for transmissions from cabinets, and so cannot normally be considered compliant with the ANFP. However where the cabinet CAL value equals or exceeds approximately 36, there is access to unshaped spectrum above 1.104 MHz. There are optional band plans for VDSL1 which could be deployed at such cabinets, however VDSL1 technology should be considered as obsolescent and for new deployments VDSL2 (see section 6.11) is much preferable in the UK.

6.11 VDSL2

The ITU standard for VDSL2 has now been approved as Recommendation G.993.2, for speeds up to 200 Mbit/s using bandwidths up to 35MHz. There is a variety of profiles/band plans intended for different national and technological applications. The profile compatible with ANFP compliance is AnnexB-998ADE17-M2x-A, enabling bit rates up to 100Mbit/s using frequencies up to 17.664 MHz. Some other profiles or Annexes are likely to be compatible with the ANFP, but these would generally offer less capability than the AnnexB-998ADE17-M2x-A profile.

6.11.1 Cancellation Status

The ANFP defines Cancellation Status (CS) in section B.3 for a single co-ordinated group of loops (i.e. where all the lines are part of the same G.993.5 vectored group). Once all VDSL2 SLCP connections at the SDF are controlled by a single vectoring engine, the CS is defined as Active; otherwise the CS is defined Inactive. In practice not all lines may be actively participating in vectoring, rather that they are capable of vectoring and are controlled by a single vectoring control entity.

Once all VDSL2 lines are vectored with active cancellation status, new lines must join the vectored group.

The value of CS also effects UPBO and controls the values of A1, B1, A2 and B2 in Table C.2 of the ANFP.

6.11.2 DPBO

The PSD shaping required to meet the requirements of Part B of the ANFP is supported through the definition of appropriate “MIB PSD Masks” which are described in section 7.2.1.1 of the VDSL2 standard.

The standard for the MIB itself that is used to set up appropriate MIB PSD masks is described in ITU-T Rec. G.997.1. The managed object is known as Downstream Power Back-Off – Shaped (DPBOSHAPED) and is described in section 7.3.1.2.13.

Nine parameters (DPBOEPSD, DPBOESCMA, DPBOESCMB, DPBOESCMC, DPBOMUS, DPBOFMIN, DPBOFMAX, DPBOLFO, DPBOMUS) need to be set up in the MIB to configure it correctly. Once this is done, any value of CAL for ANFP use can be selected by choosing an appropriate value for another MIB parameter, DPBOESEL. System vendors should be able to assist in setting these parameters correctly so that particular ANFP Part B masks are complied with.

6.11.3 UPBO

There are two modes defined in the ANFP that are applicable to VDSL2 UPBO. Guidance is provided for operators using the static mode, from section C.3.1 of the ANFP, in section 6.11.3.1 and for those using dynamic mode, from section C.3.2 of the ANFP, in section 6.11.3.2.

6.11.3.1 Static Mode UPBO

VDSL2 upstream signals are primarily subject to far end crosstalk (FEXT) as an interference source. At the time of writing they are the only upstream DSL signals that are limited in this way, all others being limited by the more severe near end crosstalk. Upstream VDSL2 upstream signals are highly likely to be coming from CPE that are at different ranges from a cabinet head-end. If they are all transmitted at the same original level they will thus have very different levels by the time they reach the head-end. If this situation were allowed the more distant CPE would suffer unfairly from the FEXT from circuits that have CPE close to the cabinet. Upstream Power Back-Off (UPBO) is employed to make this situation more equitable, lowering the transmit power of the closer CPE to lower the FEXT they couple into distant CPE. The use of UPBO is mandated in section C.3.1 of the ANFP through the parts of the mask that are dependent on the k10 value (those parts in the US1 band between 3.75 and 5.2 MHz and in the US2 band between 8.5 and 12MHz). k10

is a measure of the loss of the loop between the customer and the cabinet hosting the SLCP. The greater k_{l0} , the greater (higher) the allowed transmit signal levels. The amount of power back-off required for a given k_{l0} to comply with the ANFP is determined by the parameters A1, B1, A2 and B2. Cabinet locations with all active lines part of a vectored group have Active Cancellation Status and may comply with parameters set at A1=60, B1=14, A2=60, and B2=12. Otherwise SLCP equipment shall comply with parameters set at A1=60, B1=21, A2=60, and B2=8.

VDSL2 technology directly supports the UPBO required by the ANFP. This is done through the UPBOPSD CO-MIB structure. For unvectored cabinet location with Inactive Cancellation Status the values of:

- a' for US1 should be set to be equal to A1=60 (2000 using the scaling defined in the MIB)
- b' for US1 should be set to be equal to B1=21 (2100 using the scaling defined in the MIB)
- a' for US2 should be set to be equal to A2=60 (2000 using the scaling defined in the MIB)
- b' for US2 should be set to be equal to B2=8 (800 using the scaling defined in the MIB)

UPBO parameters for vectored cabinets with Active Cancellation Status may be configured in a corresponding way.

k_{l0} can be estimated by the modem itself if the CO-MIB value UPBOKLF is set to zero.

System vendors should be able to assist in setting these parameters correctly so that particular ANFP Part C.3.1 masks are complied with.

The accuracy of the estimation of k_{l0} by the DSLAM's modem is important for obtaining the correct degree of UPBO. Communication providers (CPs) are urged to ensure that modems used are able to estimate k_{l0} correctly so that the ANFP is complied with. Accuracy of k_{l0} estimation is a known issue as the VDSL2 standard doesn't mandate a method. In particular many modems may have difficulty estimating k_{l0} accurately if there are bridge-taps on the loop plant, especially if those bridge-taps happen to cause notches in transmission within the applicable pass bands. Bridge taps are not likely to be present in the Openreach part of the sub-loop, but are likely to be present in customer wiring.

VDSL2 defines the alternative electrical length estimation method (ELE-M1) to estimate k_{l0} , which is typically more accurate than the default method. This mechanism is defined in Section 7.2.1.3.2.1.2 of G.993.2. CPs should consider requesting this option when deploying VDSL2 systems under ANFP section C.3.1. Alternatively the MIB parameter UPBOKLF could be set to one, forcing the use of the k_{l0} value defined by MIB parameter UPBOKL, and this value could be set by some proprietary technique with appropriate accuracy.

6.11.3.2 Dynamic Mode UPBO

The dynamic PSD mask specification is defined in Section C.3.2 of the ANFP, which for VDSL2 systems only applies to upstream using UPBO. Dynamic PSD mask specification could be used with technologies other than VDSL2 as long as they are capable of dynamic line by line PSD control that meets the requirements. This section clarifies what it means to comply with the dynamic PSD mask specification, and provides some examples of compliant PSDs. There are two criteria which compliant systems must meet to use the dynamic PSD mask specification: a PSD mask constraint on every line (described in Section 6.11.3.2.1), and a normalised average PSD constraint which the ensemble of all lines at an SLCP must meet for each network operator (described in Section 6.11.3.2.2).

The PSD mask constraint allows some lines to transmit up to 5 dB higher power at some frequencies. However, the average PSD constraint mandates that other lines lower their power at those frequencies,

such that the average PSD mask is 2 dB or more below the static mask. This allows some flexibility to dynamically optimize transmit spectra for particular service level targets under individual noise conditions.

6.11.3.2.1 Dynamic UPBO PSD Mask

Denote the PSD mask defined in Section C.3.1, on line n as $umask_n(f)$ dBm/Hz, where on line n , $kI0 = kI0_n$. The PSD mask that is actually complied with on line n is denoted as $amask_n(f)$ dBm/Hz. Compliance can be expressed in terms of $amask_n(f) - umask_n(f)$, and so the expression for this difference is simplified here.

Assuming that $\max(0, kI0) = kI0$ in Table C.2, the entries with UPBO can be written as

$$amask_n(f) = \min(LM, 3.5 - A_i - B_i\sqrt{f} - kI0\sqrt{f}) \text{ dBm/Hz}$$

with f in MHz and where $i = 1, 2$, and LM is the Limit Mask defined in ITU-T G.993.2 for 998ADE17-M2x-A. The static mask $umask_n(f)$ for unvectored systems (i.e. Inactive Cancellation Status) is defined with $A1 = A2 = 60$, $B1 = 21$, and $B2 = 8$. The following analysis shows examples of Dynamic UPBO using the unvectored parameters but Section 6.11.3.2 could equally be applied to systems using the vectored parameters. The term $-kI0\sqrt{f}$ approximates the loop insertion loss, which is estimated by the transceivers to be approximately equal to the insertion gain of the loop expressed in dB, $kI0\sqrt{f} \approx 10\log_{10}(|H(f)|^2)$.

Dynamic PSD mask conformance specifies that each line meet a PSD mask in Table C.2 of the ANFP with $A1=55$, $B1=21$, $A2=55$, and $B2=8$. The difference between this and the static PSD mask specified in Section C.3.1 is that the values of $A1$ and $A2$ are 5 dB lower for the dynamic PSD mask than for the static PSD mask. This causes the dynamic PSD mask to be 5 dB above the static PSD mask, so that $amask_n(f) \leq umask_n(f) + 5$ dB, for all n . This is re-written

$$amask_n(f) - umask_n(f) \leq 5 \text{ dB}$$

Assuming that the UPBO is active so that $amask_n(f)$ is below the limit mask, LM, which is true for loop lengths up to about 850 m for US1, and for loop lengths up to about 300 m for US2:

$$\begin{aligned} amask_n(f) - umask_n(f) &= 3.5 - A_i - B_i\sqrt{f} - kI0\sqrt{f} - (3.5 - 60 - [21 \text{ or } 8]\sqrt{f} - kI0\sqrt{f}) \\ &= 60 - A_i + ([21 \text{ or } 8] - B_i)\sqrt{f} \end{aligned}$$

or,

$$\text{For the US1 band (3.75 to 5.2 MHz): } amask_n(f) - umask_n(f) = 60 - A1 + (21 - B1)\sqrt{f}$$

$$\text{For the US2 band (8.5 to 12 MHz): } amask_n(f) - umask_n(f) = 60 - A2 + (8 - B2)\sqrt{f}$$

The PSD mask that is actually complied with on line n is $amask_n(f)$, which can be defined by any values of $A1$, $B1$, $A2$, and $B2$ such that both the PSD mask and normalized average PSD constraints of Section 4.3.1 and Section C.3.2 are satisfied. However, some practical limits may be imposed by standards compliant systems; in ITU-T G.997.1 (G.ploam), parameter A_i ranges from 40 dBm/Hz to 80.95 dBm/Hz in steps of 0.01 dBm/Hz; and parameter B_i ranges from 0 to 40.95 dBm/Hz in steps of 0.01 dBm/Hz. Also, $A_i = 40$ dBm/Hz, $B_i = 0$ dBm/Hz is a special configuration to disable UPBO in the respective upstream band.

Both the mask constraint and the normalized average constraint can be stated in terms of $amask_n(f) - umask_n(f)$. So, within the bounds of these constraints, the mask can be raised or lowered by a constant amount $(60 - A_i)$ that can be different in each band. The mask can also be varied with respect to its slope in a way proportional to \sqrt{f} , specifically by $(21 - B1)\sqrt{f}$ in the US1 band, and by $(8 - B2)\sqrt{f}$ in the US2 band; which again can be different in each band.

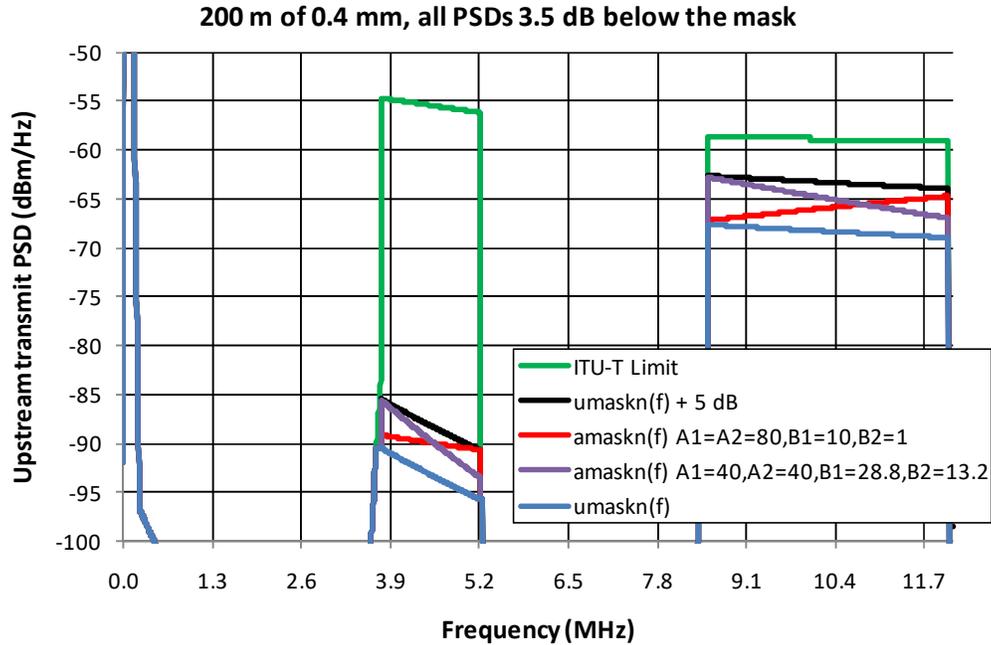


Figure 29 - Some examples of actual transmit PSDs, $amask_n(f)$, that comply with the 5 dB maximum mask constraint on a 200 m loop. The black curve is the maximum mask. The red and purple curves show the two cases of \sqrt{f} shaping made possible by varying B1 and B2 (and A1 and A2).

Figure 29 shows a dynamic PSD mask with a flat PSD variation, only varying A_i , as $umask_n(f) + 5$ dB. It also shows cases with \sqrt{f} shaping where B1 and B2 vary. The plot shows “PSD templates” which are 3.5 dB below the masks; these are the most a system can actually transmit while ensuring compliance with a PSD mask and without accounting for gain scaling (variation in g_i values).

Operators should be careful to conform to the UPBO specifications. For example, the values of A_i and B_i shown in Figure 29 should not be used in general for all loop lengths, they are instead only applicable for defining a mask which is then to be used only for loops about 200 m long. Also, when line lengths change or when lines are added or removed from an SLCP, then dynamic PSD mask values may need to be recomputed in order to be compliant.

6.11.3.2.2 Normalised Average PSD Constraint

The normalised average PSD is defined mathematically in Section 4.3.1 of the ANFP. Compliance with the normalized average as defined in Sections C.3.2 and 4.3.1 depends on the actual PSD masks of multiple lines of each operator at an SLCP. From Section 4.3.1, the normalized average PSD constraint is

$$10 \text{Log}_{10} \left(\frac{1}{N} \sum_{n=1}^N 10^{(amask_n(f) - umask_n(f))/10} \right) \leq -2 \text{ dB}$$

for each network operator at that SLCP.

Using the equations in the previous section, in the above formula $amask_n(f) - umask_n(f)$ can be substituted by

$amask_n(f) - umask_n(f) = 60 - A_{1n} + (21 - B_{1n}) \sqrt{f}$ in the US1 band from 3.75 to 5.2 MHz, and $amask_n(f) - umask_n(f) = 60 - A_{2n} + (8 - B_{2n}) \sqrt{f}$ in the US2 band from 8.5 to 12 MHz.

Here the A_i and B_i values need to be indexed by line, n , since multiple lines are included in the normalised average PSD constraint. Two examples of sets of compliant PSD masks are shown.

Average PSD Example 1: A network operator wants to increase power on one line that needs it, while the other lines are running with excess margin and can lower their power. The network operator has six lines at an SLCP ($N = 6$). One line uses a dynamic PSD mask with $A_1=55$, $B_1=21$, $A_2=55$, and $B_2=8$, which is 5 dB above the static PSD mask at all frequencies. The other five lines all use a dynamic PSD mask with $A_1=70$, $B_1=21$, $A_2=70$, and $B_2=8$, which is 10 dB below the static PSD mask at all frequencies. Then,

$$10\text{Log}_{10}\left(\frac{1}{N}\sum_{n=1}^N 10^{(amask_n(f)-umask_n(f))/10}\right) = -2.14 \text{ dB} \leq -2 \text{ dB}$$

and the normalised average PSD constraint is satisfied.

Average PSD Example 2: A network operator wishes to employ a form of spectral shaping to boost the power on high frequencies on one line, while lowering the power at high frequencies on other lines. The network operator has 10 lines at an SLCP ($N = 10$). One line uses a dynamic PSD mask with $A_1=80$, $A_2=80$, $B_1=10$, and $B_2=1$; which is one of the cases shown in Figure 29. The other nine lines use a dynamic PSD mask with $A_1=47.5$, $A_2=47.5$, $B_1=28.8$, $B_2=13.2$; which uses the same B_1 and B_2 as the other case shown in Figure 29, but with 7.5 dB less power in the US1 and US2 bands.

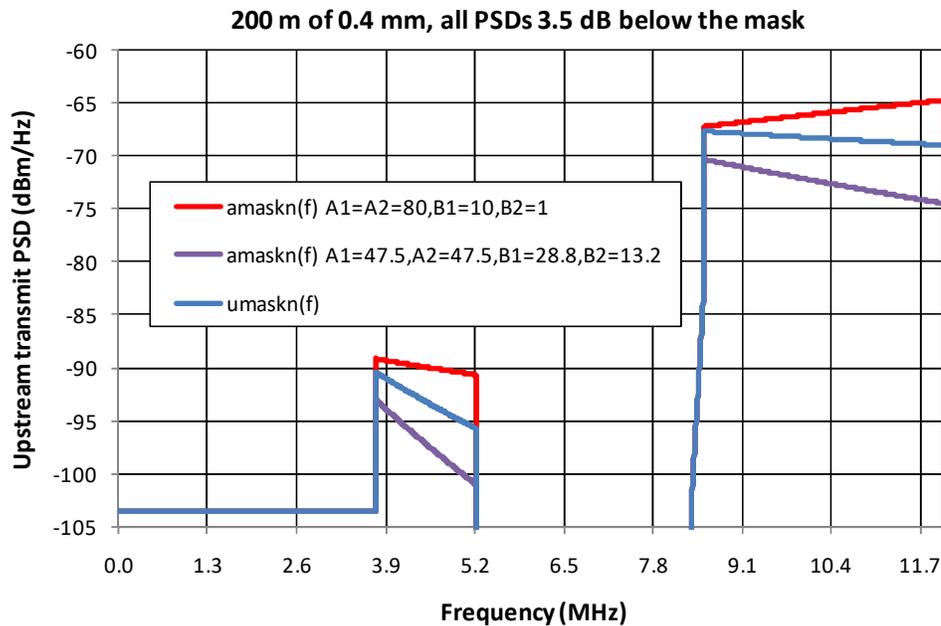


Figure 30 - The PSDs used in Average PSD Example 2

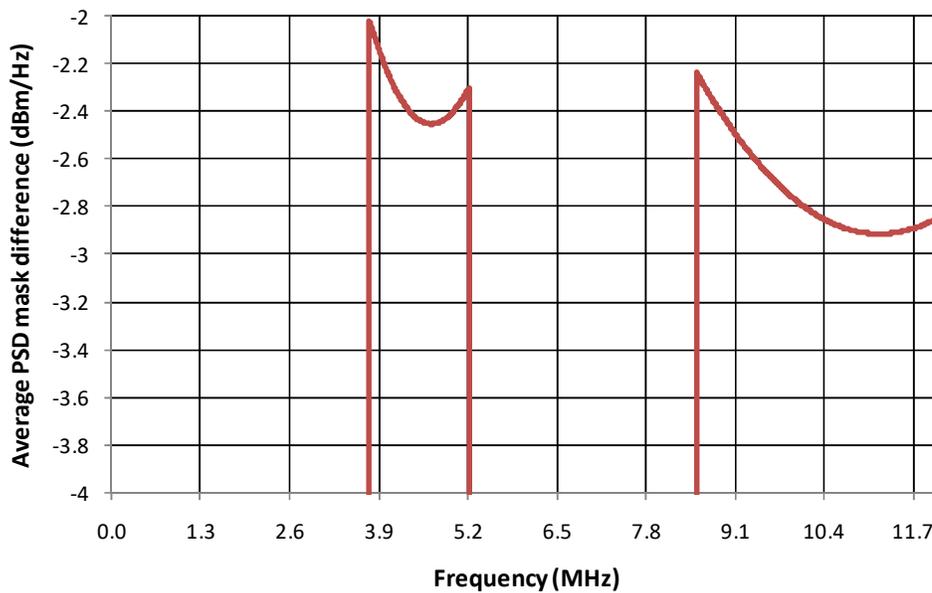


Figure 31 - The Average PSD of Example 2

Figure 31 shows the average PSD of Example 2, $10\text{Log}_{10}\left(\frac{1}{N}\sum_{n=1}^N 10^{(amask_n(f)-umask_n(f))/10}\right)$, which is seen to be below -2 dB at all frequencies and so the normalised average PSD constraint is satisfied.

The constraints on dynamic UPBO parameters in the US1 band are independent of the constraints on dynamic UPBO parameters in the US2 band. So, the US1 and US2 bands could be optimized separately with different dynamic UPBO values in each band.

6.12 FAST

FAST is a recommendation defined by the ITU G.9700 (PSD) and G.9701 (transmission system) for a TDD based transmission system, capable of using the spectrum between 2 and 212MHz in both directions. The profiles compatible with Part E and F ANFP compliance are 106a, 106b and 212a. The ANFP defines FSTART which is the start frequency for FAST. The value of FSTART is equal for upstream and downstream transmission. FSTART allows a reduced start frequency while maintaining compatibility with VDSL2. In order to be fully compliant the PSD below FSTART must additionally be shaped, which can be done through an additional standardised MIB parameter(s). By default the value of FSTART is determined by CGAL and Table E.1 of the ANFP. The larger CGAL the lower FSTART. FAST deployment at the cabinet location has CGAL = 0 and FSTART = 18.3195MHz. Section 6.12.7 provides detail on the default and alternative start frequency specifications.

ANFP parts E & F have been included which allow transmission of FAST spectrum between 2 and 212 MHz. Part F provides the limits applicable to FAST modems and can only be used when communicating with DSLAM operating under Part E. Part E provides the limits applicable to FAST DSLAMs deployed either co-located with existing Part B (VDSL2) locations or closer to the customer premise than the existing Part B location.

The ANFP defines different PSD masks for upstream and downstream FAST. The downstream mask between 29.96325MHz and 112.401MHz is higher than the upstream. This higher downstream mask is intended for use only on cables that leave the PCP and remain underground for a distance of approximately

100m of 0.5mm gauge copper cable. Underground cables have a lower propensity to cause interference to nearby radio users due to additional attenuation from the ground. It is the responsibility of the operator to maintain EMC compliance when setting the Downstream PSD and a level lower than the ANFP mask may need to be set in practice. Refer to section 6.12.1 for guidance on the safe use of the downstream FAST mask

Figure 32 shows the frequency allocation for VDSL2 and FAST using the default FSTART specification and FAST deployed at the SDF location:

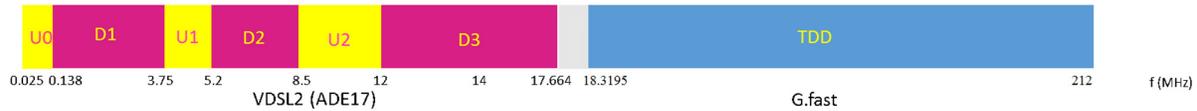


Figure 32 - VDSL and FAST frequency allocation

6.12.1 Guidance on Downstream PSD to prevent radio interference

This section considers radio interference between 30 and 106MHz. The ANFP Parts E define the downstream FAST PSD as the maximum of the ITU-T G.9700 masks LPM_106high and LPM_212. Figure 33 shows the two masks. The LPM_106high and LPM_212 are members of separate classmasks for PSD control, see section 6.12.4.

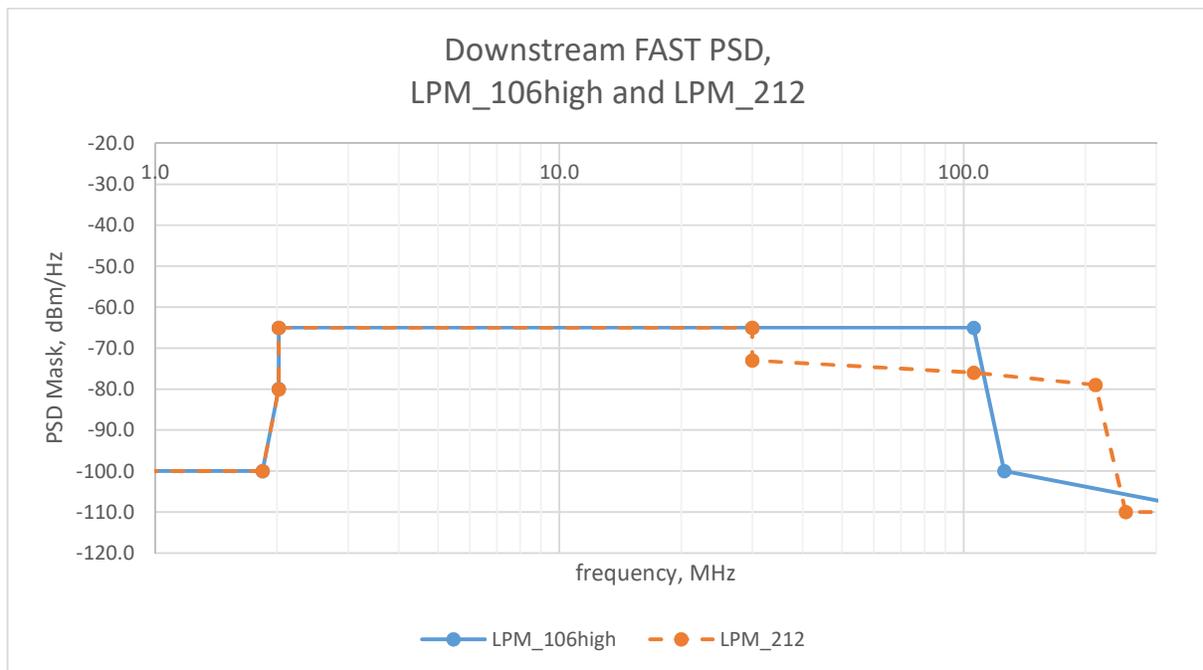


Figure 33 – FAST downstream PSDs

Note: LPM_212 corresponds to the upstream ANFP mask.

	LPM_106high	LPM_212
2.01825	-65	-65
29.96325	-65	-65
29.96335	Interp	-73
105.984	-65	-76
126	-100	Interp
212	Interp	-79
252	Interp	-110
424	-110	-110
Note: Interp means that the value at this frequency can be obtained by linear interpolation on a linear frequency scale		

Table 13: FAST breakpoints for LPM_106high and LPM_212

The downstream ANFP mask follows the ITU-T LPM_106high mask from 30 to 106 MHz, which is higher than the ITU-T LPM_212 mask. Depending on how the outside plant influences emissions, it may be appropriate to follow the LPM_212 mask from 30 to 106 MHz to limit emissions.

Currently the overarching regulatory EMC legislation applicable to the BT access network is the EU EMC Directive 2014/30/EU [4]. Generally, compliance for equipment is demonstrated by compliance with Harmonised EMC Standards that give “presumption of conformity” with the essential requirement of the Directive.

Compliance with emission limits in harmonised standards has been a major factor in defining PSD masks for DSL technologies to reduce the risk of interference being caused to nearby radio users. The emissions from underground and overhead cables are different and the latest downstream PSD mask (LPM_106high) was established based on measurements of emissions from underground topologies.

The upstream PSD mask defined in Part F of the current ANFP [1], and the downstream PSD mask previously defined in Part E of ANFP v7.1 (LPM_212) were based on emission measurements from overhead cables. EMC compliance cannot be assumed, particularly between 30 and 106MHz for equipment using the LPM_106high mask as in Part E of the current ANFP [1], when the network cables appear above ground close to the G-SDF. In this case careful consideration needs to be given to the actual downstream PSD used to ensure EMC compliance. The aim should be to ensure that at the point where the network cables appear above ground the attenuation of the loop means the downstream PSD at that point is at or below the upstream PSD Mask. Use of notching in particular frequency bands could also be considered in anticipation of, or to resolve, interference issues.

The boosted PSD only applies to the downstream PSD and not the upstream FAST PSD which remains unchanged and lower. This is due to the upstream transmitter being connected to cabling that is above ground, and also likely to be closer to radio receiving equipment. It may also be connected via in-home wiring that is outside the control of the network operator so proximity to radio receivers and level of emissions are unknown.

In considering the appropriate downstream PSD mask to use for FAST systems the deployment scenario must be considered in conjunction with the cable and connection point shielding from a given deployment location (G-SDF).

Operators should consider the following aspects in relation to downstream PSD compliance:

- a) Shielding of DSLAM cabinets
 - downstream PSD is highest at the injection location and so the DPU/DSLAM including any connection point must be sufficiently shielded
- b) Underground or overhead cabling
 - Emissions from underground cables tend to be lower than from overhead cables due to the additional attenuation provided by the ground. DPUs connected to overhead cable sections may need to use a reduced PSD between 30-106 MHz, below LPM_106high, unless a properly shielded cable is used.
- c) Cable attenuation to the point where cables comes above ground
 - Cables to a customer premise may be constructed from both underground and overhead segments. In some areas cables are mainly underground in the initial segment from the PCP but may change to overhead closer to the customer. If the initial underground segment is sufficiently long the FAST downstream PSD should be attenuated to acceptable levels before the overhead section.

6.12.2 Vectoring and TDD

Two critical aspects of FAST deployment are the use of vectoring to cancel crosstalk and time division duplexing (TDD). In a section of network all FAST modems are required to be connected to a single coordinated group, where all lines are connected and co-ordinated together. Co-ordination is both to enable synchronisation of time division duplexing (TDD) and vectoring crosstalk cancellation between the lines in the group. This is specified in ANFP Section 4.1.1. Practically in the short term all FAST CPE downstream of a FAST DSLAM and sharing the same cables will be connected to that single FAST DSLAM or FAST Distribution Point Unit (DPU).

6.12.3 Handshake carriers

In order to be compliant with the ANFP, downstream G.994.1 handshake carriers must be shaped below the limit defined in G.994.1.

The maximum power level for each carrier is defined in ANFP section E.5 and is a function of CAL and CGAL. Co-ordinated Group Assigned Loss (CGAL) describes the electrical length of the cables between an SDF site (VDSL2) and a connected G-SLCP, where the FAST lines are a co-ordinated group at the G-SLCP.

If the FAST is injected at the same location as the VDSL2 then CGAL is zero and the maximum power level that can be transmitted on the downstream handshake carriers is the same as the requirements for VDSL2 deployed compliant with Part B of the ANFP.

If the FAST is injected closer to the customer than the VDSL2 injection location then CGAL will be greater than zero and the carrier powers have to be calculated using the formulas defined in ANFP section E.5. Some examples for different combinations of CAL and CGAL are provided in Table E.6 of the ANFP.

While transmitting handshake tones below 2 MHz a FAST modem must conform to the handshake PSD mask defined in ANFP section E.4.3 above 2MHz. Practically the FAST component of the modem must not inject signals above 2 MHz during the handshake phase of initialisation.

6.12.4 Downstream PSD

The PSD shaping required to meet the requirements of Part E of the ANFP is supported through the definition of the appropriate “downstream MIB PSD Mask” which is described in section 7.3.1.1 of G.9701.

The standard for the MIB itself that is used to set up appropriate MIB PSD masks is described in ITU-T Rec. G.997.2. The managed object is known as Downstream PSD mask (MIBPSDMASKds) and is described in section 7.1.2.5.

MIBPSDMASK and possibly also sub-carrier mask (CARMASK) need to be configured so that the transceivers apply the proper PSD shaping mask (PSM) and Low-frequency edge stop-band mask (LESM)

System vendors should be able to assist in setting these parameters correctly so that particular ANFP Part E masks are complied with.

The PSD is dependent on injection location relative to the Part B (VDSL2) injection location as defined by CGAL.

The downstream ITU limit PSD mask (LPM) are grouped into two LPM classes:

- classmask_1, comprising of LPM_106 and LPM_212
- classmask_2, comprising of LPM_106high

The downstream ANFP mask is the maximum of the LPM_212 and LPM_106high masks.

All classmasks, with appropriate shaping, are compliant with the ANFP but operators should refer to section 6.12.1 for guidance on preventing radio interference.

When considered acceptable from an EMC perspective transmission at the full ANFP mask between 30 and 106MHz can be achieved by configuring classmask_2 and LPM_106high.

6.12.5 Upstream PSD

The PSD shaping required to meet the requirements of Part F of the ANFP is supported through the definition of appropriate “MIB PSD Mask” configured through the same mechanisms described in section 6.12.4.

6.12.6 UPBO

The Part F ANFP PSD mask used by FAST systems does not require UPBO and does not require the same UPBO configuration required for VDSL2 systems to be compliant with the ANFP.

However, vectoring may not entirely remove the need for UPBO to improve spectral compatibility between FAST modems operating on loops of different lengths deployed in the same binder. System vendors should be able to assist in setting UPBO parameters correctly to optimise performance of their equipment.

Although the ANFP PSD masks defined for transmission from the NTP do not explicitly require UPBO for FAST, FAST CPEs are required to support the mandatory UPBO feature of G.9701.

6.12.7 Compatibility of FAST and VDSL

Figure 34 shows a typical way of ensuring spectral compatibility of VDSL and G.fast. Here, the operating frequencies of VDSL and FAST do not overlap, either since VDSL is on a long loop and so only transmits below FSTART (Default, ANFP Section E.4.2), or by design (Alternative, ANFP Section E.4.3). Note, however, that overlap is not precluded with Alternative.

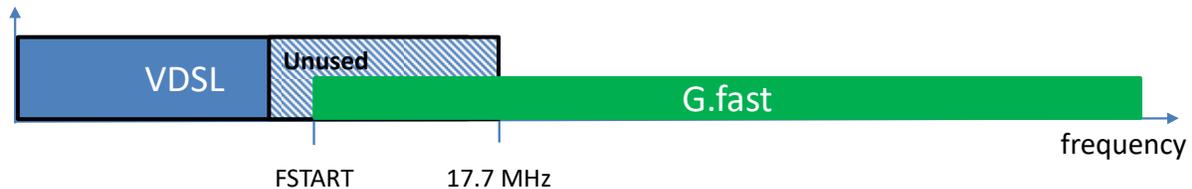


Figure 34 - FAST extending down into VDSL frequency bands.

6.12.7.1 Default

In ANFP Section E.4.2, Default, FAST can transmit at -65 dBm/Hz down to frequency FSTART. Below FSTART the roll-off PSD is as defined in ITU-T G.9700 and G.9701.

For CGAL > 7 dB, as CGAL increases FSTART decreases; this is because as loop length increases the Maximum Usable Frequency (MUF) of VDSL decreases. This allows FAST to use high VDSL band frequencies that are unused by VDSL on long loops. This is described in ND1520 [5] as Option 4, Variable split frequency per DSLAM (semi static), and it is also called frequency reuse.

6.12.7.2 Alternative

ANFP Section E.4.3, Alternative, requires documented commercial agreement for a given SDF and associated G-SDFs, and as such is subject to consensus between DSLAM operator(s) and relevant CPs. Without such agreement, ANFP Section E.4.3 does not apply.

ANFP Section E.4.3 reflects two options described and analysed in detail in ND1520[5]: Option 3, Re-farming, and Option 5, Variable split frequency per line or per vector group (dynamic).

Re-farming re-assigns some high frequencies of VDSL over to FAST. Re-farming increases FAST performance and reach, while sometimes reducing the maximum attainable VDSL data rate, thereby performing a trade-off between FAST and VDSL. Re-farming may be applied to a given geographic area or to a set of cabinets or DSLAMs. With re-farming, FAST transmits in frequencies above the alternative start frequency, FSTART, and VDSL transmits primarily in frequencies below (FSTART – guard-band), for some guard-band between VDSL and FAST. There should be no significant crosstalk between FAST and VDSL with re-farming.

Variable split frequency per line or per vector group (dynamic) typically is enabled with Dynamic Spectrum Management (DSM). DSM is typically implemented by a spectrum management centre and can vary FSTART per DSLAM or per vector group. DSM typically also shapes the VDSL and FAST transmit spectra to enable spectral compatibility. ND1518[6], Data Sharing for DSM, describes ways of implementing DSM in multi-operator scenarios.

The condition of VDSL transmitting above FSTART is called overlap. Overlap is simplified if FAST transmits downstream only in VDSL downstream frequencies[5]. FAST upstream may also transmit in VDSL upstream frequencies if FSTART is below 12 MHz. Overlap generally precludes vectoring. Overlapping can cause instabilities to VDSL2 due to time-varying crosstalk from FAST, particularly upstream, and then Dynamic Line Management (DLM) can help mitigate such instabilities.

6.12.8 G-SLCP locations

The guidelines document helps operators understand how to deploy equipment that is compliant with the ANFP. For FAST, the ANFP specifies what is required to operate at a G-SLCP either co-located with an existing PCP (where VDSL2 may have been deployed) or closer to the customer premises.

It is recognised that ubiquitous ultrafast coverage is not possible using equipment solely located at existing PCPs, and that co-ordinated group size limitations may impose an upper bound on the level of service take up from locations supporting large numbers of lines. For these reasons, deployment closer to the customer premises is likely to be necessary.

The complex optimisation of new FAST injection points in the D-side network would need to account for length distribution of D-side and possible new injection locations (affecting achievable performance), deployment cost, and target service offer. This includes the number of lines servable from a given location or co-ordinated group (affecting maximum service take up), deployment cost, local siting and power issues, self-install and FAST equipment chosen. Such practicalities will complicate real deployments. The following illustrates some of the factors in the trade-offs involved in optimising availability, service speed, and cost:

Figures 4 and 5 in [7] include an aggregated view of the D-side distribution of the Openreach network.

Figure 35 shows an indicative rate versus length curve for FAST profile 106b operating with FSTART ranging from 18.3195 to 3.0015MHz, actual performance will vary greatly depending on the chosen equipment and deployment locations. Figure 36 shows a similar rate versus reach curve but for profile 212a.

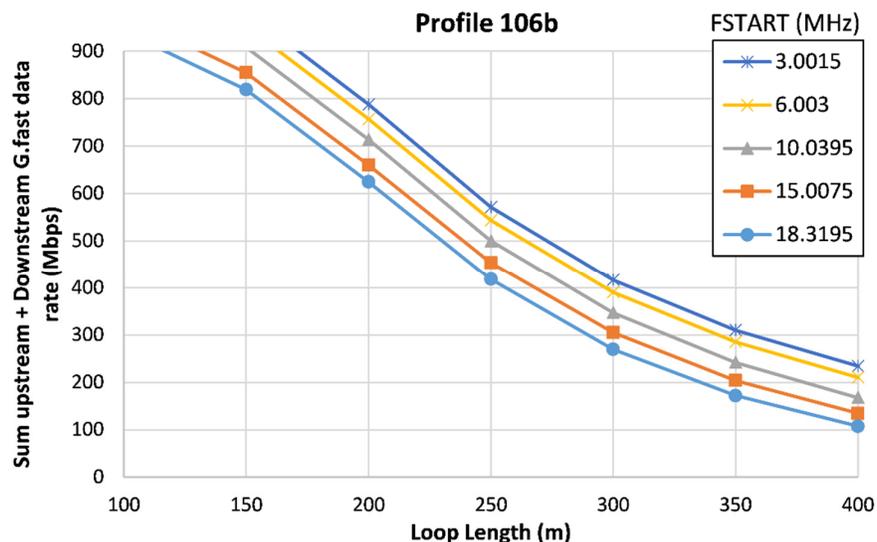


Figure 35 - Profile 106b FAST indicative aggregate rate versus reach.

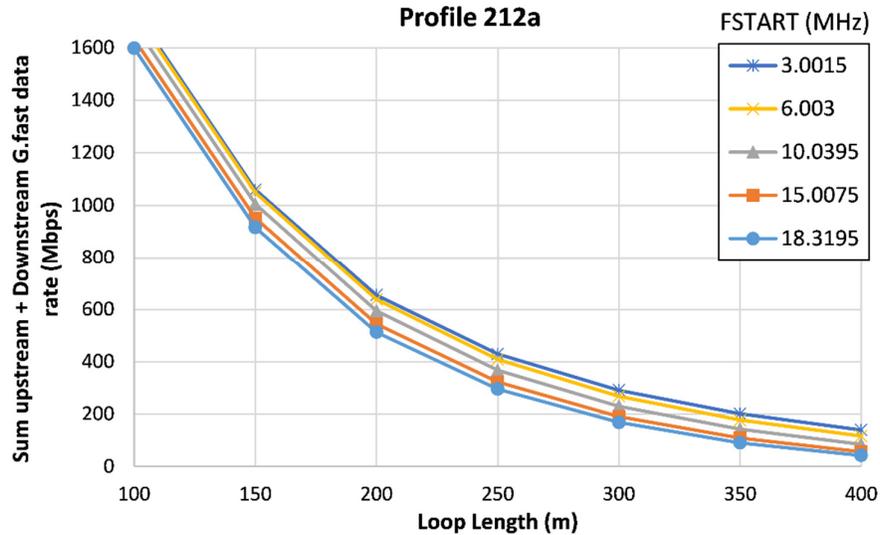


Figure 36 - Profile 212a FAST indicative aggregate rate versus reach.

A fully optimised techno-economic trade-off, as described above, for a specific PCP area would be best determined with more detailed knowledge of the plant topology than an aggregated view. The topology of two cabinets in two nominally similar locations may have very different cable structure and premises density, which would result in different conclusions on the optimal numbers and locations of G-SLCPs.

History

Document history		
1	August 2005	First Issue
2	March 2007	Updated to take account of updating of BT ANFP to Issue 4
Version 3.1.1	September 2011	Updated to take account of updating of BT ANFP to version 5.1.1
Version 3.1.2	July 2012	Broken reference in section 6.5 removed
Version 4.1.1	July 2016	Updated to take account of updating of BT ANFP to version 6.1.1
Version 5.1.1	April 2019	Updated to take account of updating of BT ANFP to version 7.1.1
Version 5.2.1	November 2019	Updated to take account of updating of BT ANFP to version 7.2.1