International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.992.5
(01/2009)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Access networks

Asymmetric digital subscriber line transceivers 2 (ADSL2) – Extended bandwidth (ADSL2plus)

Recommendation ITU-T G.992.5

ITU-T

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
General	G.900–G.909
Parameters for optical fibre cable systems	G.910–G.919
Digital sections at hierarchical bit rates based on a bit rate of 2048 kbit/s	G.920–G.929
Digital line transmission systems on cable at non-hierarchical bit rates	G.930–G.939
Digital line systems provided by FDM transmission bearers	G.940–G.949
Digital line systems	G.950–G.959
Digital section and digital transmission systems for customer access to ISDN	G.960–G.969
Optical fibre submarine cable systems	G.970–G.979
Optical line systems for local and access networks	G.980–G.989
Access networks	**G.990–G.999**
QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
ACCESS NETWORKS	G.9000–G.9999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T G.992.5

Asymmetric digital subscriber line transceivers 2 (ADSL2) – Extended bandwidth (ADSL2plus)

Summary

Recommendation ITU-T G.992.5 describes asymmetrical digital subscriber line (ADSL) transceivers on a metallic twisted pair that allows high-speed data transmission between the network operator end (ATU-C) and the customer end (ATU-R), using extended bandwidth. This Recommendation defines a variety of frame bearers in conjunction with one of two other services, or without underlying service, dependent on the environment:

1) ADSL transmission simultaneously on the same pair with voiceband service.
2) ADSL transmission simultaneously on the same pair with integrated services digital network (ISDN) (see Appendix I or II or Recommendation ITU-T G.961) services.
3) ADSL transmission without underlying service, optimized for deployment with ADSL over voiceband service in the same binder cable.
4) ADSL transmission without underlying service, optimized for deployment with ADSL over ISDN service in the same binder cable.
5) ADSL transmission with extended upstream bandwidth, simultaneously on the same pair with voice band service.

ADSL transmission on the same pair with voiceband services and operating in an environment with TCM-ISDN (see Appendix III of Recommendation ITU-T G.961) services in an adjacent pair is for further study.

This Recommendation specifies the physical layer characteristics of the extended bandwidth asymmetric digital subscriber line (ADSL) interface to metallic loops. As compared to the ADSL2 transceiver defined in Recommendation ITU-T G.992.3, the operating modes use double the downstream bandwidth. When operating on the same pair with voiceband services, an additional operating mode is defined, using the double upstream bandwidth.

This Recommendation has been written to help ensure the proper interfacing and interworking of ADSL transmission units at the customer end (ATU-R) and at the network operator end (ATU-C) and also to define the transport capability of the units. Proper operation shall be ensured when these two units are manufactured and provided independently. A single twisted pair of telephone wires is used to connect the ATU-C to the ATU-R. The ADSL transmission units must deal with a variety of wire pair characteristics and typical impairments (e.g., crosstalk and noise).

An extended bandwidth ADSL transmission unit (ADSL2plus transceiver) can simultaneously convey all of the following: a number of downstream frame bearers; a number of upstream frame bearers; a baseband plain old telephone service (POTS)/ISDN duplex channel; and ADSL line overhead for framing, error control, operations and maintenance. Systems support a net data rate ranging up to a minimum of 16 Mbit/s downstream and 800 kbit/s upstream. Support of net data rates above 16 Mbit/s downstream and support of net data rates above 800 kbit/s upstream are optional.

This Recommendation includes mandatory requirements, recommendations and options; these are designated by the words shall", "should" and "may", respectively. The word "will" is used only to designate events that take place under some defined set of circumstances. This Recommendation is written as a delta Recommendation relative to Recommendation ITU-T Rec. G.992.3. For the clauses which have been changed, this Recommendation contains complete replacement text (unless explicitly indicated). For the clauses which have not been changed, this Recommendation contains only the clause heading, with reference to Recommendation ITU-T G.992.3.

This Recommendation defines several optional capabilities and features:

– transport of STM and/or ATM and/or Packets;
– transport of a network timing reference;
– multiple latency paths;

– multiple frame bearers;
– short initialization procedure;
– dynamic rate repartitioning;
– seamless rate adaptation;
- extended impulse noise protection;
- erasure decoding;
- virtual noise;
- impulse noise monitor.

It is the intention of this Recommendation to provide, by negotiation during initialization, for U-interface compatibility and interoperability between transceivers complying with this Recommendation, and between transceivers that include different combinations of options.

Annex C to this Recommendation has been published independently due to its size and its specific structure.

History

This Recommendation describes extended bandwidth ADSL2 (ADSL2plus) transceivers, as a delta to the second generation ADSL (ADSL2 – Recommendation ITU-T G.992.3).

This Recommendation has been written to provide additional features relative to Recommendation ITU-T G.992.3, which was approved on 22 April 2009. Several potential improvements have been identified to better address higher data rates for shorter loops and longer reach for high data rates. This Recommendation provides a new ADSL U-interface specification, including the identified improvements, which ITU-T believes will be most helpful to the ADSL industry.

Relative to Recommendation ITU-T G.992.3, the following application-related feature has been added:

– Improved support for services requiring high downstream data rates (e.g., broadband entertainment services).

Relative to Recommendation ITU-T G.992.3, the following PMS-TC-related feature has been added:

– Support of up to 16 Reed-Solomon codewords per symbol;

Relative to Recommendation ITU-T G.992.3, the following PMD-related features have been added:

– Extended downstream bandwidth to 2.208 MHz (512 subcarriers) for all operation modes (POTS/ISDN/all-digital mode);
– Downstream spectrum control with individual maximum transmit PSD at U-C reference point per subcarrier, under operator control through CO-MIB, allows configuration per the regional requirements (e.g., North America, Europe or Japan) and deployment scenarios (e.g., central office or remote).
– Downstream spectrum shaping during showtime (shaped transmit PSD in the passband, i.e., non-flat) for improved downstream transmit PSD flexibility.

Through negotiation during initialization, the capability of equipment to support this and other ITU-T G.992.x-series ADSL Recommendations is identified. For reasons of interoperability, equipment may choose to support multiple Recommendations, such that it is able to adapt to the operating mode supported by the far-end equipment.

Source

Recommendation ITU-T G.992.5 was approved on 13 January 2009 by ITU-T Study Group 15 (2009-2012) under Recommendation ITU-T A.8 procedures.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure e.g. interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU [had/had not] received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

CONTENTS

		Page
1	Scope	1
2	References	2
3	Definitions	3
4	Abbreviations and acronyms	3
5	Reference models	3
6	Transport protocol-specific transmission convergence (TPS-TC) function	3
	6.1 Transport capabilities	3
7	Physical media-specific transmission convergence (PMS-TC) function	3
	7.1 Transport capabilities	3
	7.2 Additional functions	3
	7.3 Block interface signals and primitives	3
	7.4 Block diagram and internal reference point signals	3
	7.5 Control parameters	4
	7.6 Frame structure	4
	7.7 Data plane procedures	5
	7.8 Control plane procedures	5
	7.9 Management plane procedures	5
	7.10 Initialization procedures	5
	7.11 On-line reconfiguration	7
	7.12 Power management mode	7
8	Physical media-dependent function	7
	8.1 Transport capabilities	7
	8.2 Additional functions	7
	8.3 Block interface signals and primitives	7
	8.4 Block diagram and internal reference point signals	7
	8.5 Control parameters	7
	8.6 Constellation encoder for data symbols	15
	8.7 Constellation encoder for synchronization and L2 exit symbols	15
	8.8 Modulation	15
	8.9 Transmitter dynamic range	17
	8.10 Transmitter spectral masks	17
	8.11 Control plane procedures	17
	8.12 Management plane procedures	17
	8.13 Initialization procedures	18
	8.14 Short initialization procedures	30
	8.15 Loop diagnostics mode procedures	30
	8.16 On-line reconfiguration of the PMD function	38

		Page
8.17	Power management in the PMD function	38
9	Management protocol-specific transmission convergence (MPS-TC) functions	38
9.1	Transport functions	38
9.2	Additional functions	38
9.3	Block interface signals and primitives	38
9.4	Management plane procedures	39
10	Dynamic behaviour	41
Annex A	Specific requirements for an ADSL system operating in the frequency band above POTS	42
A.1	ATU-C functional characteristics (pertains to clause 8)	42
A.2	ATU-R functional characteristics (pertains to clause 8)	47
A.3	Initialization	50
A.4	Electrical characteristics	51
Annex B	Specific requirements for an ADSL system operating in the frequency band above ISDN as defined in Appendices I and II of Recommendation ITU-T G.961	52
B.1	ATU-C functional characteristics (pertains to clause 8)	52
B.2	ATU-R functional characteristics (pertains to clause 8)	57
B.3	Initialization	60
B.4	Electrical characteristics	60
Annex C	Specific requirements for an ADSL system operating in the same cable as ISDN as defined in Appendix III of Recommendation ITU-T G.961	62
Annex D	ATU-C and ATU-R state diagrams	63
Annex E	POTS and ISDN basic access splitters	63
Annex F	ATU-x performance requirements for region A (North America)	64
F.1	Performance requirements for operation of ADSL over POTS (Annex A)	64
F.2	Performance requirements for operation of all-digital mode ADSL (Annex I)	64
Annex G	ATU-x performance requirements for region B (Europe)	65
G.1	Performance requirements for operation of ADSL over POTS (Annex A)	65
G.2	Performance requirements for operation of ADSL over ISDN (Annex B)	65
G.3	Performance requirements for operation of all-digital mode ADSL (Annex I)	65
G.4	Performance requirements for operation of all-digital mode ADSL (Annex J)	65
Annex H	Specific requirements for a synchronized symmetrical DSL (SSDSL) system operating in the same cable binder as ISDN as defined in Appendix III of Recommendation ITU-T G.961	66
Annex I	All-digital mode ADSL with improved spectral compatibility with ADSL over POTS	67
I.1	ATU-C functional characteristics (pertains to clause 8)	67

I.2 ATU-R functional characteristics (pertains to clause 8) 70

Page

I.3 Initialization 72

I.4 Electrical characteristics 72

Annex J – All-digital mode ADSL with improved spectral compatibility with ADSL over ISDN 74

J.1 ATU-C functional characteristics (pertains to clause 8) 74

J.2 ATU-R functional characteristics (pertains to clause 8) 75

J.3 Initialization 77

J.4 Electrical characteristics 78

Annex K – TPS-TC functional descriptions 79

Annex L – *This annex is intentionally left blank* 81

Annex M – Specific requirements for an ADSL system with extended upstream bandwidth, operating in the frequency band above POTS 82

M.1 ATU-C functional characteristics (pertains to clause 8) 82

M.2 ATU-R functional characteristics (pertains to clause 8) 83

M.3 Initialization.. 86

M.4 Electrical characteristics 87

Annex N – *This annex is intentionally left blank*.. 88

Annex O – *This annex is intentionally left blank*.. 89

Annex P – Reduced downstream aggregate transmit power requirements............................. 90

Appendix I – ATM layer to physical layer logical interface 91

Appendix II – Compatibility with other customer premises equipment................................ 92

Appendix III – The impact of primary protection devices on line balance 93

Appendix IV – PSD template to be used in capacity calculations with in-band transmit spectrum shaping 94

Appendix V – Constraints on delay, impulse noise protection, overhead rate, and net data rate when bonding 96

Appendix VI – Packet layer to physical layer logical interface... 98

Appendix VII – ADSL2plus automoding 99

Appendix VIII – Impact of loop and ATU impedance mismatch on the Hlog accuracy 100

Bibliography.. 101

Recommendation ITU-T G.992.5

Asymmetric digital subscriber line transceivers 2 (ADSL2) – Extended bandwidth (ADSL2plus)

1 Scope

For the interrelationships of this Recommendation with other ITU-T G.99x-series Recommendations, see [b-ITU-T G.995.1].

This Recommendation describes the interface between the telecommunication network and the customer installation in terms of their interaction and electrical characteristics. The requirements of this Recommendation apply to a single asymmetric digital subscriber line (ADSL).

ADSL provides a variety of frame bearers in conjunction with other services:

- ADSL service on the same pair with voiceband services (including plain old telephone service (POTS) and voiceband data services). The ADSL service occupies a frequency band above the voiceband service, and is separated from it by filtering.
- ADSL service on the same pair as integrated services digital network (ISDN) service, as defined in Appendices I and II of [ITU-T G.961]. The ADSL service occupies a frequency band above the ISDN service, and is separated from it by filtering.
- ADSL service on the same pair with voiceband services (e.g., POTS and voiceband data services), and with TCM-ISDN services as defined in Appendix III of [ITU-T G.961] on an adjacent pair. The ADSL service occupies a frequency band above the voiceband service, and is separated from it by filtering.
- ADSL service with extended upstream bandwidth on the same pair with voiceband services (including POTS and voiceband data services). The ADSL service occupies a frequency band above the voiceband service, and is separated from it by filtering.

ADSL also provides a variety of frame bearers without baseband services (i.e., POTS or ISDN) being present on the same pair.

- ADSL service on a pair, with improved spectral compatibility with ADSL over POTS present on an adjacent pair.
- ADSL service on a pair, with improved spectral compatibility with ADSL over ISDN present on an adjacent pair.

In the direction from the network operator to the customer premises (i.e., the downstream direction), the frame bearers provided may include low-speed frame bearers and high-speed frame bearers; in the other direction from the customer premises to the central office (i.e., the upstream direction), only low-speed frame bearers are provided.

The transmission system is designed to operate on two-wire twisted metallic copper pairs with mixed gauges. This Recommendation is based on the use of copper pairs without loading coils, but bridged taps are acceptable in all but a few unusual situations.

An overview of digital subscriber line transceivers can be found in [b-ITU-T G.995.1].

Specifically, this Recommendation:

- defines the transmission protocol specific transmission convergence sub-layer for ATM, STM and Packet transport through the frame bearers provided;
- defines the combined options and ranges of the frame bearers provided;
- defines the line code and the spectral composition of the signals transmitted by both ATU-C and ATU-R;

- defines the initialization procedure for both the ATU-C and the ATU-R;
- specifies the transmit signals at both the ATU-C and ATU-R;
- describes the organization of transmitted and received data into frames;
- defines the functions of the operations, administration and management (OAM) channel.

In separate annexes, it also:

- Describes the transmission technique used to support the simultaneous transport of voiceband services and frame bearers (ADSL over POTS, Annex A) on a single twisted-pair.
- Describes the transmission technique used to support the simultaneous transport of ISDN services as defined in Appendices I and II of [ITU-T G.961], and frame bearers (ADSL over ISDN, Annex B) on a single twisted-pair.
- Describes the transmission technique used to support the transport of only frame bearers on a pair, with improved spectral compatibility with ADSL over POTS present on an adjacent pair (all-digital mode, Annex I).
- Describes the transmission technique used to support the transport of only frame bearers on a pair, with improved spectral compatibility with ADSL over ISDN present on adjacent pair (all-digital mode, Annex J).
- Describes the transmission technique used to support the simultaneous transport of voiceband services and frame bearers for extended upstream bandwidth operation (EUADSL2plus over POTS, Annex M) on a single twisted-pair.

This Recommendation defines the minimal set of requirements to provide satisfactory simultaneous transmission between the network and the customer interface of a variety of frame bearers and other services such as POTS or ISDN. This Recommendation permits network providers an expanded use of existing copper facilities. All required physical layer aspects to ensure compatibility between equipment in the network and equipment at a remote location are specified. Equipment may be implemented with additional functions and procedures.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.961] Recommendation ITU-T G.961 (1993), *Digital transmission system on metallic local lines for ISDN basic rate access*.

[ITU-T G.992.3] Recommendation ITU-T G.992.3 (2009), *Asymmetric digital subscriber line transceivers 2 (ADSL2)*.

[ITU-T G.994.1] Recommendation ITU-T G.994.1 (2003), *Handshake procedures for digital subscriber line (DSL) transceivers*.

[ITU-T G.996.1] Recommendation ITU-T G.996.1 (2001), *Test procedures for digital subscriber line (DSL) transceivers*.

3 Definitions

See clause 3 of ITU-T G.992.3, modified as follows:

~~**3.31 power cutback (PCB)**: Reduction of the transmit PSD level (expressed in dB) in any one direction, relative to the nominal transmit PSD level. The same transmit PSD level reduction is applied over the whole frequency band (i.e., flat cutback).~~

3.31 power cutback (PCB): Scalar valued parameter controlling the difference (expressed in dB), between the nominal transmit PSD level and the reference transmit PSD level (REFPSD), in any one direction. In case of non-unity tss_i, a frequency dependent transmit PSD level reduction could result (i.e., ceiled cutback).

~~**3.33 reference transmit power spectral density level (REFPSD)**: The nominal transmit PSD level, lowered by the power cutback, in any one direction.~~

3.33 reference transmit power spectral density level (REFPSD): The nominal transmit PSD level, lowered by the power cutback (PCB), in any one direction.

4 Abbreviations and acronyms

See clause 4 of ITU-T G.992.3.

5 Reference models

See clause 5 of ITU-T G.992.3, adding the following text immediately before clause 5.1.

ITU-T G.992.5 provides tools for the operator of the access network to control the ADSL transmit PSD and aggregate power in the downstream and upstream directions. Depending on regional spectrum management guidelines, these tools may be needed to enable remote ADSL deployment. In this case, the ATU-C is located in a remote cabinet located between the central office and the customer premises, rather than the access node.

6 Transport protocol-specific transmission convergence (TPS-TC) function

6.1 Transport capabilities

See clause 6 of ITU-T G.992.3.

7 Physical media-specific transmission convergence (PMS-TC) function

7.1 Transport capabilities

See clause 7.1 of ITU-T G.992.3.

7.2 Additional functions

See clause 7.2 of ITU-T G.992.3.

7.3 Block interface signals and primitives

See clause 7.3 of ITU-T G.992.3.

7.4 Block diagram and internal reference point signals

See clause 7.4 of ITU-T G.992.3.

7.5 Control parameters

See clause 7.5 of ITU-T G.992.3.

7.6 Frame structure

See clause 7.6 of ITU-T G.992.3.

7.6.1 Derived definitions

See clause 7.6.1 of ITU-T G.992.3.

7.6.2 Valid framing configurations

See clause 7.6.2 of ITU-T G.992.3, modified as follows

Table 7-8 displays the allowable range of each PMS-TC control parameter. Additionally, the control parameters shall satisfy some relationships to one another for the set of control parameter values to be valid as displayed in Table 7-8. Some ranges of the valid control parameter values are expressed in terms of NSC, which is the number of subcarriers as defined in clause 8.8.1.

...

Table 7-8 – Valid framing configurations

Parameter	Capability
...	...
Relationship of $N_{FEC\,0}$ and D_0	For the downstream latency path #0, configurations that satisfy the following relationship are valid: $(N_{FEC\,0} - 1) \times (D_0 - 1) \leq$ ~~254 × 63 = 16002~~24000 For the upstream latency path #0, configurations that satisfy the following relationship are valid: $(N_{FEC\,0} - 1) \times (D_0 - 1) \leq 254 \times 7 = 1778$
...	...
Relation of S_p and M_p	Configurations that satisfy the following relationship are valid: M_p /~~2~~3 $\leq S_p \leq 32 \times M_p$ (see Note 1). For the downstream latency path #0, additional valid configurations are: $M_0 /16 \leq S_0 \leq M_0$ /~~2~~3
...	...
Delay constraints	Configurations that satisfy the following relationship are valid: ~~1/2~~1/3 $\leq S_p \leq 64$ (see Note 3) For the downstream latency path #0, additional valid S_0 values are: $1/16 \leq S_0 <$ ~~1/2~~1/3
...	...

NOTE 1 – This condition is a bound on the number of mux data frames per symbol.

NOTE 2 – The 0.1 kbit/s overhead rate lower bound corresponds to an $SEQ_p = 2$ (see Table 7-14) and an overhead channel period of 160 ms.

NOTE 3 – This condition puts bounds on the number of FEC codewords per symbol.

~~NOTE 4 – Setting MSG_{min} higher than 28 kbit/s may cause configuration errors and reduce the maximal achievable net data rate.~~

NOTE – The ITU-T G.992.5 PMS-TC function differs from the ITU-T G.992.3 PMS-TC function only in the relationship of N_{FEC0} and D_0, the number of Mux Data Frames per symbol and the number of FEC codewords per symbol.

7.6.3 Mandatory configurations

See clause 7.6.3 of ITU-T G.992.3, modifying Table 7-9 as follows:

Table 7-9 – Mandatory downstream control parameter support for latency path #0

Parameter	Capability
…	…
S_0	~~1/2~~1/3 $\leq S_0 < 64$ Support of additional optional S_0 values is indicated during initialization, through $S_{0\,min}$, with $1/16 \leq S_{0\,min} \leq$ ~~1/2~~1/3. All values of S_0, with $S_{0\,min} \leq S_0 <$ ~~1/2~~1/3, shall be supported.
…	…
Relationship of N_{FEC0} and D_0	Configurations that satisfy the following relationship shall be supported: $(N_{FEC0} - 1) \times (D_0 - 1) \leq 254 \times 63 = 16002$.

7.7 Data plane procedures

See clause 7.7 of ITU-T G.992.3.

7.8 Control plane procedures

See clause 7.8 of ITU-T G.992.3.

7.9 Management plane procedures

See clause 7.9 of ITU-T G.992.3.

7.10 Initialization procedures

See clause 7.10 of ITU-T G.992.3, modified as follows:

Table 7-18 – Format for PMS-TC capability list information

…	…
Spar(2) bit	**Definition of related Npar(3) octets**
…	…
Downstream PMS-TC latency path #0 supported (always set to 1)	Parameter block of 6 octets that describes the maximum net_max downstream rate, downstream $S_{0\,min}$, ~~and~~ downstream D_0 and the downstream relationship of N_{FEC0} and D_0 values supported in the latency path #0. The unsigned 12-bit net_max value is the data rate divided by ~~4000~~8000. The net_max downstream rate shall be greater than or equal to the maximum required downstream data rate for each TPS-TC type that is supported by the ATU. The supported range of S_0 values shall be indicated by its lower bound $S_{0\,min}$. $S_{0\,min}$ shall equal 1/(n+1), with n coded as an unsigned 4-bit value in the 1 to 15 range. The D_0 values supported shall be individually indicated with 1 bit per value. The "24000 bytes interleaver size" bit indicates the support of different relationships of N_{FEC0} and D_0. If set to ZERO, the ATU shall support all configurations of supported N_{FEC0} and D_0 such that $(N_{FEC0} - 1) \times (D_0 - 1) \leq$ 16'002. If set to ONE, the ATU shall support all configurations of supported N_{FEC0} and D_0 such that $(N_{FEC0} - 1) \times (D_0 - 1) \leq$ 24'000.

Table 7-18 – Format for PMS-TC capability list information

Upstream PMS-TC latency path #0 supported (always set to 1)	Parameter block of 3 octets that describes the maximum net_max upstream rate and downstream D_0 values supported in the latency path #0. The unsigned 12-bit net_max value is the data rate divided by ~~4000~~8000. The net_max upstream rate shall be greater than or equal to the maximum required upstream data rate for each TPS-TC type that is supported by the ATU. The D_0 values supported shall be individually indicated with 1 bit per value.
Downstream PMS-TC latency path #1 supported	Parameter block of 4 octets that describes the maximum net_max downstream rate, downstream $R_{1\ max}$, and downstream $D_{1\ max}$ supported in the latency path #1. The unsigned 12-bit net_max value is the data rate divided by ~~4000~~8000. $R_{1\ max}$ is an unsigned 4-bit value and shall be one of the valid R_p values divided by 2. $D_{1\ max}$ is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid D_p values.
Upstream PMS-TC latency path #1 supported	Parameter block of 4 octets that describes the maximum net_max upstream rate, upstream $R_{1\ max}$, and upstream $D_{1\ max}$ supported in the latency path #1. The unsigned 12-bit net_max value is the data rate divided by ~~4000~~8000. $R_{1\ max}$ is an unsigned 4-bit value and shall be one of the valid R_p values divided by 2. $D_{1\ max}$ is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid D_p values.
Downstream PMS-TC latency path #2 supported	Parameter block of 4 octets that describes the maximum net_max downstream rate, downstream $R_{2\ max}$, and downstream $D_{2\ max}$ supported in the latency path #2. The unsigned 12-bit net_max value is the data rate divided by ~~4000~~8000. $R_{2\ max}$ is an unsigned 4-bit value and shall be one of the valid R_p values divided by 2. $D_{2\ max}$ is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid D_p values.
Upstream PMS-TC latency path #2 supported	Parameter block of 4 octets that describes the maximum net_max upstream rate, upstream $R_{2\ max}$, and upstream $D_{2\ max}$ supported in the latency path #2. The unsigned 12-bit net_max value is the data rate divided by ~~4000~~8000. $R_{2\ max}$ is an unsigned 4-bit value and shall be one of the valid R_p values divided by 2. $D_{2\ max}$ is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid D_p values.
Downstream PMS-TC latency path #3 supported	Parameter block of 4 octets that describes the maximum net_max downstream rate, downstream $R_{3\ max}$, and downstream $D_{3\ max}$ supported in the latency path #3. The unsigned 12-bit net_max value is the data rate divided by ~~4000~~8000. $R_{3\ max}$ is an unsigned 4-bit value and shall be one of the valid R_p values divided by 2. $D_{3\ max}$ is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid D_p values.
Upstream PMS-TC latency path #3 supported	Parameter block of 4 octets that describes the maximum net_max upstream rate, upstream $R_{3\ max}$, and upstream $D_{3\ max}$ supported in the latency path #3. The unsigned 12-bit net_max value is the data rate divided by ~~4000~~8000. $R_{3\ max}$ is an unsigned 4-bit value and shall be one of the value R_p values divided by 2. $D_{3\ max}$ is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid D_p values.
NOTE – By construction of the ADSL2plus framing, the message-based overhead data rate is strictly smaller than 64 kbit/s. Hence, the ITU-T G.994.1 phase of initialization should not request a minimum value of 64 kbit/s.	

• • •

The $S_{0\ min}$ value shall be less than or equal to ~~1/2~~1/3 (i.e., n ≥ ~~1~~2). If the $S_{0\ min}$ octet (see Table 7-18c) is not included in the CL or CLR message, the $S_{0\ min}$ value shall be set equal to ~~1/2~~1/3 (implicit indication). The S_0 value selected during the exchange phase (see Table 7-7 and clause 7.10.3) shall be equal to or higher than the highest of the $S_{0\ min}$ values indicated in the CL and CLR message.

• • •

7.11 On-line reconfiguration

See clause 7.11 of ITU-T G.992.3.

7.12 Power management mode

See clause 7.11 of ITU-T G.992.3.

8 Physical media-dependent function

8.1 Transport capabilities

See clause 8.1 of ITU-T G.992.3.

8.2 Additional functions

See clause 8.2 of ITU-T G.992.3.

8.3 Block interface signals and primitives

See clause 8.3 of ITU-T G.992.3.

8.4 Block diagram and internal reference point signals

See clause 8.4 of ITU-T G.992.3.

8.5 Control parameters

8.5.1 Definition of control parameters

See clause 8.5.1 of ITU-T G.992.3, adding the following text immediately after Table 8-6:

The tss_i values depend on CO-MIB settings (see [ITU-T G.997.1]) and on local capabilities and are exchanged in the ITU-T G.994.1 phase. The tss_i values are determined by the ATU transmit function:

– For the upstream direction, the CO-MIB settings consist of a per-upstream subcarrier indication of which subcarriers may be in the upstream SUPPORTEDset and which subcarriers shall not be in the upstream SUPPORTEDset. This information is conveyed from ATU-C to ATU-R in the ITU-T G.994.1 CL upstream spectrum shaping parameter block and is used by the ATU-R (in combination with local restrictions) to determine which subcarriers to include in the upstream SUPPORTEDset (see clause 8.13.2.4).

– For the downstream direction, the CO-MIB settings consist of a per-downstream subcarrier indication of which subcarriers may be in the downstream SUPPORTEDset and which subcarriers shall not be in the downstream SUPPORTEDset. This information is used by the ATU-C (in combination with local restrictions) to determine which subcarriers to include in the downstream SUPPORTEDset (see clause 8.13.2.4).

– For the downstream direction, the CO-MIB settings also include the downstream PSD mask applicable at the U-C2 reference point (see clause 5). This MIB PSD mask may impose PSD restrictions in addition to the Limit PSD mask defined in the relevant Annex, as relevant for the chosen application option. This information is used by the ATU-C (in combination with local restrictions) to determine which subcarriers to include in the downstream SUPPORTEDset (see clause 8.13.2.4) and to determine the level of spectrum shaping (i.e., tss_i value) to be applied to these subcarriers. The downstream PSD mask specified through the CO-MIB shall satisfy the requirements defined in the remainder of this clause.

The downstream PSD mask in the CO-MIB (exchanged between NMS and access node over the Q reference point, see Figure 5-1 of [ITU-T G.997.1]) shall be specified through the downstream power back-off-shaped (DPBOSHAPED, see clause 7.3.1.2.13 of [ITU-T G.997.1]) or through a set of breakpoints (PSDMASKds, see 7.3.1.2.9 of [ITU-T G.997.1]).

- When specified through a set of breakpoints, the access node shall pass these breakpoints (PSDMASKds) to the ATU-C over the gamma reference point.
- When specified through the DPBO (i.e., DPBOESEL > 0, see clause 7.3.1.2.13 of [ITU-T G.997.1]), the access node shall pass the set of breakpoints of the modified downstream PSD mask (see clause 7.3.1.2.13 of [ITU-T G.997.1]) to the ATU-C over the gamma reference point.

At the Q and gamma reference points, each breakpoint shall consist of a subcarrier index *t* and a MIB PSD mask level (expressed in dBm/Hz) at that subcarrier. The set of breakpoints can then be represented as $[(t_1, PSD_1), (t_2, PSD_2), ..., (t_N, PSD_N)]$. The subcarrier index shall be coded as an unsigned integer in the range from $roundup(f\_pb\_start/\Delta f)$ to $rounddown(f\_pb\_stop/\Delta f)$, where f_pb_start and f_pb_stop are the lower and higher edge, of the passband respectively and Δf is the subcarrier spacing defined in clause 8.8.1. The passband is defined in Annexes A, B or I, as relevant to the selected application option. The MIB PSD mask level shall be coded as an unsigned integer representing the PSD mask levels 0 dBm/Hz (coded as 0) to –127.5 dBm/Hz (coded as 255), in steps of 0.5 dBm/Hz, with valid range 0 to –95 dBm/Hz. The maximum number of breakpoints is 32. The corresponding MIB PSD mask for each frequency *f* shall be defined as follows:

- f_lm_start = frequency at which the flat extension below f_1 intersects the limit mask (0 Hz if no intersect).
- f_lm_stop = frequency at which the flat extension above f_N intersects the limit mask.
- At frequencies below f_1 and at frequencies above f_N, the MIB PSD mask shall be obtained as follows:

$$MIB\ PSD\ mask(f) = \begin{cases} Limit\ mask(f) & f < f\_lm\_start \\ PSD_1 & f\_lm\_start \le f \le f_1 \\ & \\ PSD_N & f_N < f \le f\_lm\_stop \\ Limit\ mask(f) & f > f\_lm\_stop \end{cases}$$

NOTE 1 – In defining the set of breakpoints of the modified downstream PSD mask (see clause 7.3.1.2.13 of [ITU-T G.997.1]), the access node may take into account whether the transceiver supports windowing or not (see clause 8.8.4).

NOTE 2 – The actual transmit PSD (at the U-C reference point), while conforming to the MIB PSD mask (received through a set of breakpoints over the gamma reference point), may significantly undershoot the MIB PSD mask in some frequency regions if the MIB PSD mask shape requires faster roll-off than is supported by the available windowing capability. Appendix IV defines the PSD template to be used in capacity calculations with in band transmit spectrum shaping, except where the transceiver supports windowing and windowing is enabled, in which case the shape of the windowing should be taken into account.

In case the downstream PSD mask in the CO-MIB is expressed as a set of breakpoints (exchanged between NMS and AN over the Q reference point, see clause 7.3.1.2.9 [ITU-T G.997.1]), the set of breakpoints shall comply to the following restrictions, and the corresponding MIB PSD mask for each frequency *f* shall be defined as following:

1) General:
   - $t_n < t_{n+1}$ for $n = 1$ to $N - 1$.
   - $f_n = t_n \times \Delta f$.
2) Low-frequency end and high-frequency end of MIB PSD mask (*f*):
   - $t_1 = roundup(f\_pb\_start/\Delta f)$ or $(73 \le t_1 \le 271)$.
   - $t_N = rounddown(f\_pb\_stop/\Delta f)$.

3) MIB PSD stopband in lower frequency part:

if ($73 \le t_1 \le 271$) then:

– $PSD_1 = -95$ dBm/Hz.

– Set of valid t_2 values is every tenth tone starting from tone 100 up until tone 280.

– The value t_1 shall be:

$$t_1 = rounddown\left(t_2 - \left(\frac{PSD_2 - PSD_1}{2.2\,\text{dB/tone}}\right)\right)$$

– At frequencies between f_1 and f_2, the MIB PSD mask is obtained by interpolation in dB on a logarithmic frequency scale as follows:

$$MIB\ PSD\ mask\ (f) = \left\{ PSD_1 + (PSD_2 - PSD_1) \times \frac{\log((f/\Delta f)/t_1)}{\log(t_2/t_1)} \quad f_1 < f \le f_2 \right.$$

4) MIB PSD inband shaping:

if $t_1 = roundup(f\_pb\_start/\Delta f)$ then, for $n = 1$ to $N - 1$:

if ($73 \le t_1 \le 271$) then, for $n = 2$ to $N - 1$:

– The inband slope shall comply to:

$$\left|\frac{PSD_{n+1} - PSD_n}{t_{n+1} - t_n}\right| \le 0.75\,\text{dB/tone}$$

– MAX (PSD_n) – MIN (PSD_n) ≤ 20 dB.

– MAX PSD of the limit mask –20 dB ≤ MAX (PSD_n) ≤ MAX PSD of the limit mask.

– The MIB PSD mask is obtained by interpolation in dB on a linear frequency scale as follows:

$$MIB\ PSD\ mask\ (f) = \left\{ PSD_n + (PSD_{n+1} - PSD_n) \times \frac{(f/\Delta f) - t_n}{t_{n+1} - t_n} \quad f_n < f \le f_{n+1} \right.$$

NOTE 3 – If the first breakpoint has subcarrier index $73 \le t_1 \le 271$, then a stopband is created in the lower frequency part of the passband, with spectrum shaping applied to the remainder of the passband. If $t_1 = roundup(f\_pb\_start/\Delta f)$, then only spectrum shaping is applied over the whole passband.

5) RFI band specification:

– An RFI band is specified in the CO-MIB PSD mask through a set of 4 breakpoints ($t(i + 1)$, $PSD(i + 1)$) to ($t(i + 4)$, $PSD(i + 4)$), as shown in Figure 8.5.1-1. In addition, the CO-MIB also contains an explicit indication that the pair ($t(i + 2)$, $t(i + 3)$) represents an RFI band (see [ITU-T G.997.1]).

– The restrictions on the breakpoints specifying an RFI band are:

$$\frac{PSD_{i+1} - PSD_{i+2}}{t_{i+1} - t_{i+2}} \le 1.5\,\text{dB/tone}$$

$$PSD_{i+2} \ge PSD\_Limitmask(f_{i+2}) - 33.5\,\text{dB}$$

$$PSD_{i+2} = PSD_{i+3}$$

$$PSD_{i+3} \ge PSD\_Limitmask(f_{i+3}) - 33.5\,\text{dB}$$

$$\frac{PSD_{i+4} - PSD_{i+3}}{t_{i+4} - t_{i+3}} \leq 1.5\,\text{dB/tone}$$

– In the RFI band, the MIB PSD mask is given by the following equations:

$$MIB\,PSD\,mask(f) = \begin{cases} PSD_{i+1} & f_{i+1} \leq f \leq f_{i+2} \\ PSD_{i+2} = PSD_{i+3} & f_{i+2} \leq f \leq f_{i+3} \\ PSD_{i+4} & f_{i+3} \leq f \leq f_{i+4} \end{cases}$$

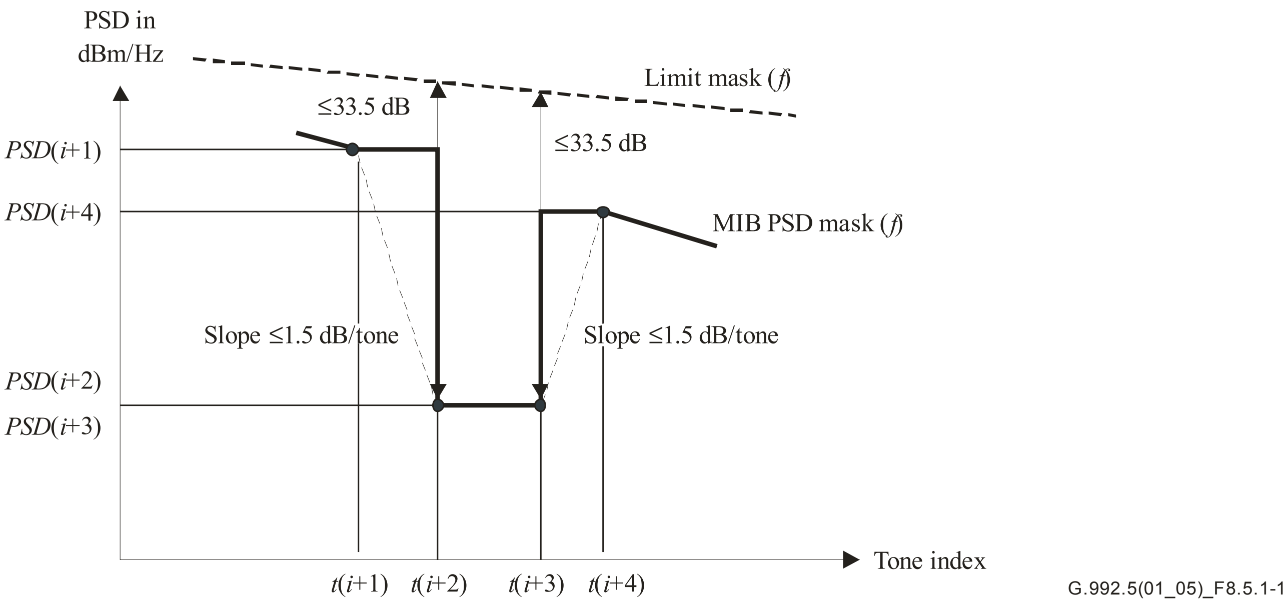


Figure 8.5.1-1 – Restrictions on breakpoints and MIB PSD mask (*f*)

The (informative) MIB PSD template is defined as the CO-MIB PSD mask – 3.5 dB, for $f\_lm\_start \leq f \leq f\_lm\_stop$, except for the MIB PSD stopband in the lower frequency part, which remains at –95 dBm/Hz, and the stopband of the RFI bands which remains at PSD($i + 2$).

The PSD mask to which the ATU-C transmitter shall comply at the U-C2 reference point shall be the minimum (at each frequency) of the limit PSD mask (specified in Annexes A, B or I) and the CO-MIB PSD mask specified through the CO-MIB.

The following figures give a number of examples of MIB PSD masks which can be constructed within the above restrictions. Figure 8.5.1-2 illustrates a number of PSD masks which introduce a stopband in the first part of the frequency band. Figure 8.5.1-3 illustrates the restrictions on the MIB PSD in band shaping. The PSD toolbox techniques shown in these figures may be combined in practice.

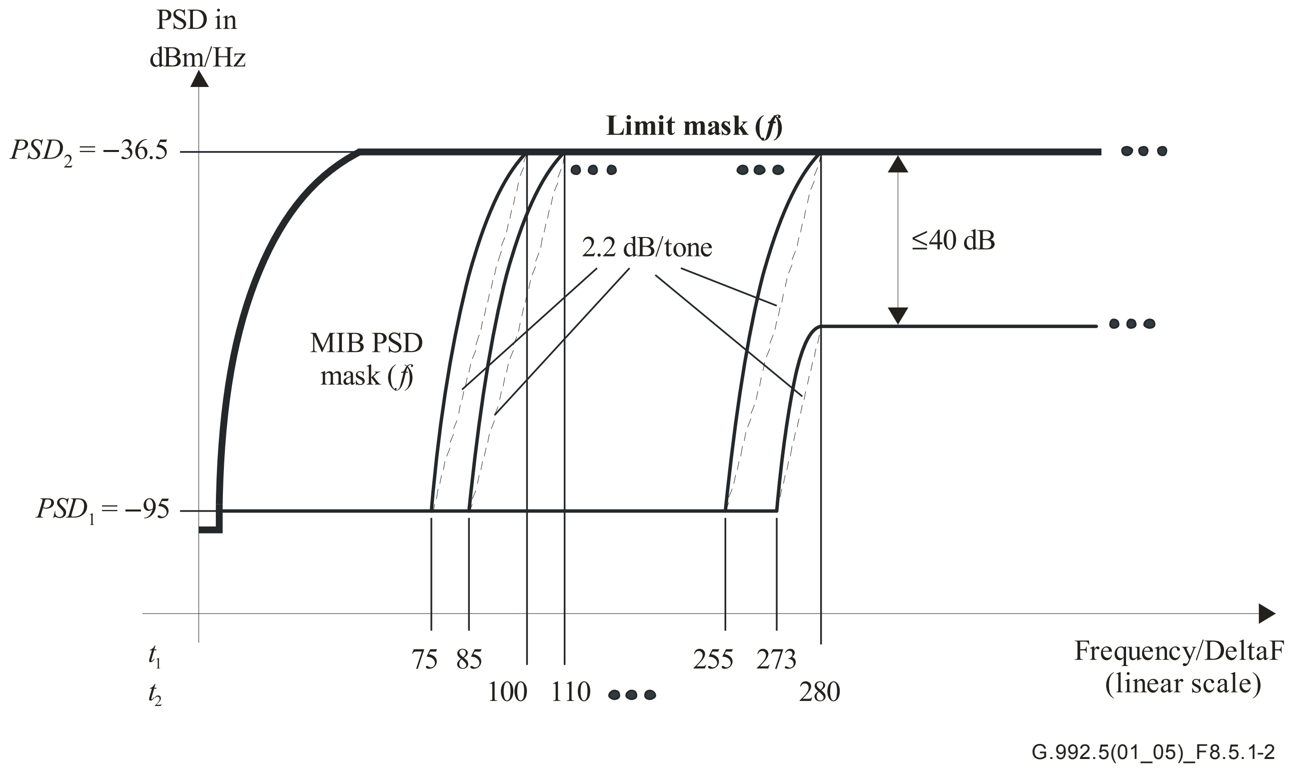


Figure 8.5.1-2 – Illustration of a stopband in the first part of the frequency band

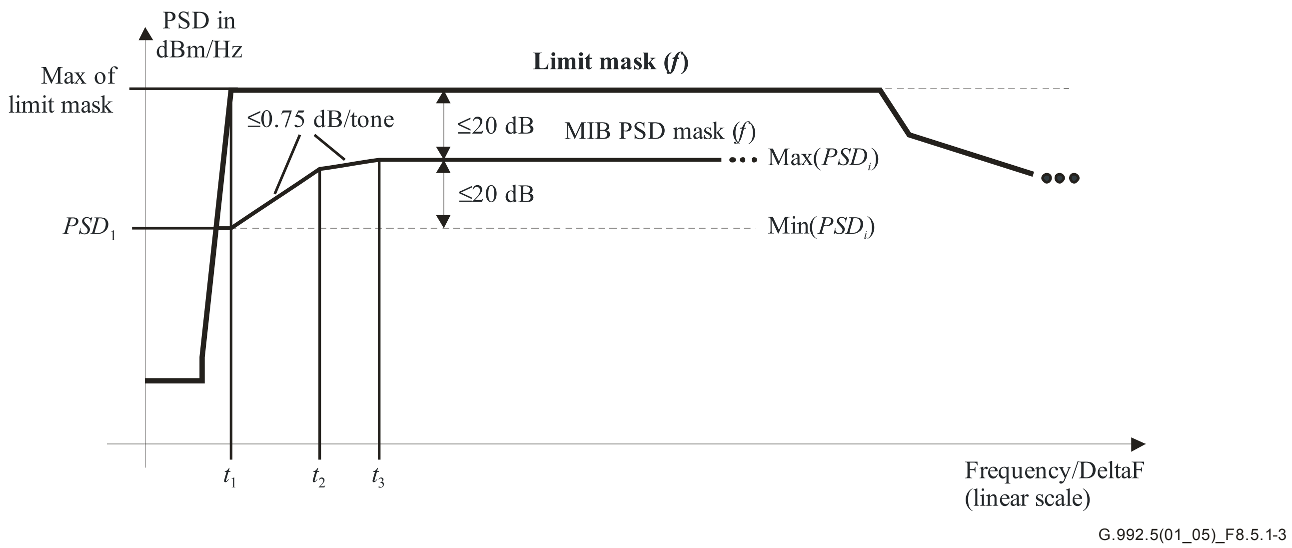


Figure 8.5.1-3 – Illustration of the restrictions on the MIB PSD in-band shaping

8.5.2 Mandatory and optional settings of control parameters

See clause 8.5.2 of ITU-T G.992.3.

8.5.3 Setting control parameters during initialization

See clause 8.5.3 of ITU-T G.992.3, modified as follows:

Table 8-11 – Format of PMD function control parameters included in MSG1

Parameter	Format
...	...
CA-MEDLEY	Unsigned 6-bit integer, 0 to 63 (times 512 symbols).
WINDOW SAMPLES	Window samples are represented by *NSCds*/64 entries. Each entry is a 16-bit unsigned integer, in multiples of 2^{-16} (see clause 8.8.4).

The value *CA-MEDLEY* represents the minimum duration (in multiples of 512 symbols) of the MEDLEY state during the initialization channel analysis phase. It can be different for the ATU-C (*CA-MEDLEYus* indicates the minimum length of the R-MEDLEY state) and the ATU-R (*CA-MEDLEYds* indicates the minimum length of the C-MEDLEY state). See clauses 8.13.5.1.4 and 8.13.5.2.4.

The PMD function control parameters exchanged in the C-MSG1 message are listed in Table 8-12. Window samples shall be included only if windowing is applied (which is indicated in C-MSG-FMT, see clause 8.13.3.1.10).

Table 8-12 – PMD function control parameters included in C-MSG1

Octet Nr [i]	Parameter	PMD format bits [8 × i + 7 to 8 × i + 0]
...	...	...
19	Reserved	[0000 0000]
20	*w*(0) (LSB)	[xxxx xxxx], bit 7 to 0
21	*w*(0) (MSB)	[xxxx xxxx], bit 15 to 8
...	...	...
18 + *NSCds*/32	*w*(*NSCds*/64 – 1) (LSB)	[xxxx xxxx], bit 7 to 0
19 + *NSCds*/32	*w*(*NSCds*/64 – 1) (MSB)	[xxxx xxxx], bit 15 to 8

...

NOTE – An extended range for g_i values can only be used if the transmit PSD function chooses to use a nominal transmit PSD level that is below the maximum transmit PSD level allowed by the CO-MIB (see clause 8.5.1) and can only be used within the transmit PSD mask limitations set by the CO-MIB.

8.5.3.3 During the exchange phase

See clause 8.5.3.3 of ITU-T G.992.3, modified as follows:

The format of the PMD function control and test parameters involved in the PARAMS messages shall be as shown in Table 8-14.

Table 8-14 – Format of PMD function control parameters included in PARAMS

Parameter	Format
...	...
Tone ordering table	Tone ordering is represented by *NSC* – 1 entries. Each entry is an ~~8~~11-bit unsigned integer, representing a subcarrier index in the 1 to *NSC* – 1 range.

The test parameters are mapped into messages using an integer number of octets per parameter value. In case the parameter value, as defined in clause 8.12.3, is represented with a number of bits that is not an integer number of octets, the parameter value shall be mapped into the least significant bits of the message octets. Unused more significant bits shall be set to 0 for unsigned parameter values and shall be set to the sign bit for signed parameter values.

The PMD function control parameters and test parameters exchanged in the C-PARAMS message are listed in Table 8-15.

Table 8-15 – PMD function control parameters included in C-PARAMS

Octet Nr [i]	Parameter	PMD format bits [8 × i + 7 to 8 × i + 0]
…	…	…
5	*SNRMus* (MSB)	[ssss ~~ssxx~~sxxx], bit ~~9 and~~10 to 8
…	…	…
13 + 2 × *NSCus*	~~Upstream tone ordering first subcarrier to map~~Reserved	~~[xxxx xxxx], bit 7 to 0~~[0000 0000]
14 + 2 × *NSCus*	Upstream tone ordering first subcarrier to map (LSB)	[xxxx xxxx], bits 7 to 0
15 + 2 × *NSCus*	Upstream tone ordering first subcarrier to map (MSB)	[0000 0xxx], bits 10 to 8
…..	…..	…..
10 + 4 × *NSCus*	Upstream tone ordering last subcarrier to map (LSB)	[xxxx xxxx], bits 7 to 0
11 + ~~3~~4 × *NSCus*	Upstream tone ordering last subcarrier to map (MSB)	[xxxx xxxx], bits ~~7 to 0~~10 to 8

The PMD function control parameters exchanged in the R-PARAMS message are listed in Table 8-16.

Table 8-16 – PMD function control parameters included in R-PARAMS

Octet Nr [i]	Parameter	PMD format bits [8 × i + 7 to 8 × i + 0]
…	…	…
5	*SNRMds* (MSB)	[ssss ~~ssxx~~sxxx], bit ~~9 and~~ 10 to8
…	…	…
13 + 2 × *NSCds*	~~Downstream tone ordering first subcarrier to map~~Reserved	~~[xxxx xxxx], bit 7 to 0~~[0000 0000]
14 + 2 × *NSCds*	Downstream tone ordering first subcarrier to map (LSB)	[xxxx xxxx], bits 7 to 0
15 + 2 × *NSCds*	Downstream tone ordering first subcarrier to map (MSB)	[0000 0xxx], bits 10 to 8
…..	…..	…..
~~11 + 3~~10 + 4 × *NSCds*	Downstream tone ordering last subcarrier to map (LSB)	[xxxx xxxx], bit 7 to 0

Table 8-16 – PMD function control parameters included in R-PARAMS

Octet Nr [i]	Parameter	PMD format bits [8 × i + 7 to 8 × i + 0]
11 + 4 × *NSCds*	Downstream tone ordering last subcarrier to map (MSB)	[0000 0xxx], bits 10 to 8

8.6 Constellation encoder for data symbols

See clause 8.6 of ITU-T G.992.3.

8.7 Constellation encoder for synchronization and L2 exit symbols

See clause 8.7 of ITU-T G.992.3.

8.8 Modulation

See clause 8.8 of ITU-T G.992.3.

8.8.1 Subcarriers

See clause 8.8.1 of ITU-T G.992.3.

8.8.2 Inverse discrete fourier transform (IDFT)

See clause 8.8.2 of ITU-T G.992.3.

8.8.3 Cyclic prefix

See clause 8.8.3 of ITU-T G.992.3, modified as follows.

With a data symbol rate of 4 kHz, a DMT subcarriers spacing of Δf = 4.3125 kHz and an IDFT size of 2 × *NSC*, a cyclic prefix of (2 × *NSC* × 5/64) samples could be used. That is,

$(2 \times NSC + 2 \times NSC \times 5/64) \times 4.0\text{ kHz} = (2 \times NSC) \times 4.3125\text{ kHz} = f_s$ (the sample frequency)

The cyclic prefix shall, however, be shortened to (2 × *NSC* × 4/64 = *NSC*/8) samples, and a synchronization symbol (with a length of 2 × *NSC* × 68/64 samples) is inserted after every 68 data symbols. That is,

$$(2 \times NSC \times 4/64 + 2 \times NSC) \times 69 = (2 \times NSC \times 5/64 + 2 \times \text{NSC}) \times 68$$

For symbols with cyclic prefix, the last *NSC*/8 samples of output of the IDFT (x_n for $n = 2 \times NSC - NSC/8$ to $2 \times NSC - 1$) shall be prepended to the block of 2 × *NSC* samples, to form a block of (2 × *NSC* × 17/16) samples. Symbols with cyclic prefix are transmitted at a symbol rate of 4.3125 × 16/17 ≈ 4.059 kHz.

In the downstream direction, the ATU-C transmitter may apply windowing. If windowing is applied, symbols with cyclic prefix shall also have a cyclic suffix. If windowing is not applied, symbols with cyclic prefix shall not have a cyclic suffix. For symbols with a cyclic suffix, the first *NSCds*/32 samples of output of the IDFT (x_n for $n = 0$ to $NSCds/32 - 1$) shall be appended to the block of (2 × *NSC* × 17/16) samples, to form a block of (2 × *NSC* × 69/64) samples. Symbols with cyclic suffix are transmitted at a symbol rate of 4.3125 × 16/17 ≈ 4.059 kHz.

The cyclic prefix (and suffix if windowing is applied) shall be used for all symbols transmitted starting from the channel analysis phase of the initialization sequence (see clause 8.13.5). Before the channel analysis phase, all symbols shall be transmitted without cyclic prefix and without cyclic suffix.. Symbols transmitted without cyclic prefix and without cyclic suffix are transmitted at a symbol rate of 4.3125 kHz.

If an oversampled IDFT is used (i.e., $N > NSC$, see clause 8.8.2), the number of cyclic prefix and cyclic suffix samples shall be adapted accordingly. For symbols with cyclic prefix, the last $N/8$ samples of output of the IDFT (x_n for $n = 2 \times N - N/8$ to $2 \times N - 1$) shall be prepended to the block of $2 \times N$ samples, to form a block of ($2 \times N \times 17/16$) samples. For symbols with cyclic suffix, the first $N/32$ samples of output of the IDFT (x_n for $n = 0$ to $N/32 - 1$) shall be appended to the block of ($2 \times N \times 17/16$) samples, to form a block of ($2 \times N \times 69/64$) samples.

8.8.4 Parallel/serial convertor

See clause 8.8.4 of ITU-T G.992.3, modified as follows.

The block of x_n samples ($n = 0$ to $2 \times NSC - 1$) shall be read out to the digital-to-analogue convertor (DAC) in sequence.

If no cyclic prefix is used, the DAC samples y_n in sequence are:

$$y_n = x_n \text{ for } n = 0 \text{ to } 2 \times NSC - 1$$

If a cyclic prefix is used, the DAC samples y_n in sequence are (see Figure 8-5):

$$y_n = x_{n + (2 \times NSC - NSC/8)} \qquad \text{for } n = 0 \text{ to } NSC/8 - 1$$

$$y_n = x_{n - (NSC/8)} \qquad \text{for } n = NSC/8 \text{ to } (17/16) \times 2 \times NSC - 1$$

If, for the downstream direction, a cyclic prefix is used and a cyclic suffix is used (windowing), then the DAC samples in sequence shall be:

$$[1-w(i)]\times prev\_x(i)+w(i)\times x\left(2\times NSC-\frac{NSC}{8}+i\right) \qquad \text{for } i=0 \text{ to } \frac{NSC}{32}-1$$

$$x\left(2\times NSC-\frac{NSC}{8}+i\right) \qquad \text{for } i=\frac{NSC}{32} \text{ to } \frac{NSC}{8}-1$$

$$x(i) \qquad \text{for } i=0 \text{ to } 2\times NSC-1$$

where the *prev_x(i)* corresponds to the cyclic suffix of the previous symbol (see clause 8.8.3). The $NSC/32$ samples in the cyclic suffix of the previous symbol and the first $NSC/32$ samples of the cyclic prefix of the current symbol are transmitted as overlapping in time, i.e., a weighted sum is transmitted. The above defined DAC sample sequence corresponds to applying a ($2 \times NSC \times 69/64$) samples window. The window in discrete time representation (set of w_i) shall defined as follows:

$$w_i \text{ is vendor discretionary} \qquad \text{for } i=0 \text{ to } \frac{NSC}{64}-1$$

$$w_i = 1-w\left(\frac{NSC}{32}-1-i\right) \qquad \text{for } i=\frac{NSC}{64} \text{ to } \frac{NSC}{32}-1$$

$$w_i = 1 \qquad \text{for } i=\frac{NSC}{32} \text{ to } 2\times NSC\times\frac{17}{16}-1$$

$$w_i = w\left(2\times NSC\times\frac{69}{64}-1-i\right) \qquad \text{for } i=2\times NSC\times\frac{17}{16} \text{ to } 2\times NSC\times\frac{69}{64}-1$$

Each of the time discrete window samples shall be represented in a 16-bit unsigned integer as a multiple of 65536, in the 0 to $1 - 2^{-16}$ range.

The window in continuous time representation ($w(t)$) shall be defined as follows:

$$w(t) = \sum_{i=0}^{2\times NSC\times\frac{69}{64}-1} \operatorname{sinc}(t\times f_s - i)\cdot w_i$$

The ATU-C shall indicate in the C-MSG-FMT message whether or not windowing is applied. In case windowing is applied, the C-MSG1 shall contain the window samples $w(i)$ for $i = 0$ to $NSC/64 - 1$ (see clause 8.5.3.2). These NSC/64 samples define the complete window of $2 \times NSC \times 69/64$ samples as defined above.

NOTE – The C-MSG1 message is transmitted in the Initialization procedures (see clause 8.13) and Short initialization procedures (see clause 8.14). It is not transmitted in the Loop diagnostics mode procedures (see clause 8.15).

If an oversampled IDFT is used (i.e., $N > NSC$, see clause 8.8.2), the number of window samples shall be adapted accordingly from the window in continuous time representation $w(t)$ to a window of $2 \times N \times 69/64$ samples. The ATU-C shall truncate in time and round samples to the same precision as the (non-oversampled) window samples communicated to the ATU-R in the C-MSG1 message. The ATU-R receiver shall take into account the error that the ATU-C transmitter may introduce through this time truncation and value rounding process.

Filtering may be applied to the sample sequence going into the DAC.

8.8.5 DAC and AFE

See clause 8.8.5 of ITU-T G.992.3, modified as follows.

The DAC produces an analogue signal that is passed through the analogue front end (AFE) and transmitted across the digital subscriber line (DSL). The analogue front end may include filtering.

If the transmit PMD function is configured in the L3 idle state, then a zero output voltage shall be transmitted at the U-C2 (for ATU-C) and the U-R2 (for ATU-R) reference point (see reference model in clause 5.4). The analogue front end may include filtering.

8.9 Transmitter dynamic range

See clause 8.9 of ITU-T G.992.3, adding the following text immediately before clause 8.9.1:

Due to the non-flat PSD used for the downstream transmitted signals, the MTPR requirements at the ATU-C are for further study.

8.10 Transmitter spectral masks

See clause 8.10 of ITU-T G.992.3, modified as follows:

In this Recommendation, Annex L is not defined.

~~Annex L: Specific requirements for a Reach Extended ADSL2 (READSL2) system operating in the frequency band above POTS:~~

- ~~L.1.2 ATU-C transmit spectral mask for overlapped spectrum reach-extended operation;~~
- ~~L.1.3 ATU-C transmit spectral mask for non-overlapped spectrum reach-extended operation;~~
- ~~L.2.2 ATU-R transmit spectral mask 1 for reach-extended operation.~~
- ~~L.2.3 ATU-R transmit spectral mask 2 for reach-extended operation.~~

8.11 Control plane procedures

See clause 8.11 of ITU-T G.992.3.

8.12 Management plane procedures

See clause 8.12 of ITU-T G.992.3.

8.12.1 ADSL line-related primitives

See clause 8.12.1 of ITU-T G.992.3.

8.12.2 Other primitives

See clause 8.12.2 of ITU-T G.992.3.

8.12.3 Test parameters

See clause 8.12.3 of ITU-T G.992.3.

8.12.4 Diagnostics mode

See clause 8.12.4 of ITU-T G.992.3.

8.12.5 Accuracy of test parameters

See clause 8.12.5 of ITU-T G.992.3.

8.12.5.1 Channel characteristics function per subcarrier (CCFps)

8.12.5.1.1 Channel attenuation in logarithmic format (HLOGps)

See clause 8.12.5.1.1 of ITU-T G.992.3, modified as follows:

The downstream HLOGps reference value shall be defined for each subcarrier as follows:

$$\text{HLOGps\_reference\_ds}(i) = \text{PSDps\_UR2}(i) - (REFPSDds + ceiled\_log\_tss_i(i))$$

• • •

The accuracy requirements for the downstream HLOGps (HLOGps_ds) shall apply only to the following subcarriers (with the corresponding frequency ranges being a part of the passband), and only if not within the downstream BLACKOUTset (see clause 8.13.2.4):

- Annexes A and I: Subcarriers 46 to ~~208~~463.
- ~~Annex L: Subcarriers 46 to 104.~~
- Annexes B, J and M: Subcarriers 92 to ~~208~~463.

The accuracy requirements for upstream HLOGps (HLOGps_us) shall apply to the subcarriers within the following frequency ranges (defined as a part of the passband), and not within the upstream BLACKOUTset (see clause 8.13.2.4):

- Annexes A and I: Subcarriers 11 to 23.
- ~~Annex L (mask 1): Subcarriers 11 to 17.~~
- Annex B: Subcarriers 36 to 53.
- Annexes J and M: Subcarriers 11 to 53.

• • •

8.13 Initialization procedures

8.13.1 Overview

See clause 8.13.1 of ITU-T G.992.3.

8.13.2 ITU-T G.994.1 phase

See clause 8.13.2 of ITU-T G.992.3, adding the following text immediately before clause 8.13.2.1:

The ITU-T G.992.5 handshake codepoints are defined in [ITU-T G.994.1].

8.13.2.1 Handshake – ATU-C

See clause 8.13.2.1 of ITU-T G.992.3.

8.13.2.1.1 CL messages

See clause 8.13.2.1.1 of ITU-T G.992.3, adding the following immediately after Table 8-20:

For operation in Annex A mode, the following additional Npar(2) codepoint is defined:

Npar(2)	**Definition for CL message**
Downstream spectrum shaping using time domain filtering only	When set to 1, the ATU-C indicates that only time domain filtering is used to shape the downstream inband spectrum.

If the ATU-C sets the "downstream spectrum shaping using time domain filtering only" bit to ONE in the CL message, the downstream tss_i values shall all be set to ONE and the ATU-C shall shape the inband transmit PSD only in the time domain, with a shape identical to the shape of the downstream Annex A PSD mask. If the ATU-C sets this bit to ZERO in the CL message, it indicates that the ATU-R shall use the downstream tss_i values as indicated in the CL message for all calculations.

The ATU-C shall set the "downstream spectrum shaping using time domain filtering only" bit to ONE in the MS message if, and only if, both the previous CL and CLR messages have this bit set to ONE.

8.13.2.2 Handshake – ATU-R

See clause 8.13.2.2 of ITU-T G.992.3.

8.13.2.2.1 CLR messages

See clause 8.13.2.2.1 of ITU-T G.992.3, adding the following text immediately after Table 8-22:

For operation in Annex A mode, the following additional Npar(2) codepoint is defined:

Npar(2)	**Definition for CLR message**
Downstream spectrum shaping using time domain filtering only	When set to 1, the ATU-R indicates that it can support processing of received signals generated with time domain only filtering of the downstream inband spectrum.

The ATU-R shall set the "downstream spectrum shaping using time domain filtering only" bit to ONE in the MS message if, and only if, both the previous CL and CLR messages have this bit set to ONE.

If the "downstream spectrum shaping using time domain filtering only" bit is set to ONE in the MS message, the ATU-R shall assume that the downstream tss_i values are all set to ONE and the ATU-R shall compute the NOMATP using a set of downstream tss_i values derived from the Annex A downstream PSD mask. If the bit is set to ZERO in the MS message, the ATU-R shall use the downstream tss_i values as indicated in the previous CL message for all calculations.

8.13.2.3 ITU-T G.994.1 transmit PSD levels

See clause 8.13.2.3 of ITU-T G.992.3.

8.13.2.4 Spectral bounds and shaping parameters

See clause 8.13.2.4 of ITU-T G.992.3, modified as follows immediately after Note 4.

– If windowing is applied in the downstream direction, the $W^2(f)$ used in Equation 8-1 is the Fourier transform of the autocorrelation function of the window $w(t)$ (see clause 8.8.4), normalized such that the integral of $W^2(f)$ is equal to unity.

– The downstream tss_i values as indicated in the ITU-T G.994.1 CL message shall be used in the channel discovery phase.

– Starting from the transceiver training phase, tss_i values for subcarriers included the downstream SUPPORTEDset shall be ceiled according to the following relationship, before being applied relative to the *REFPSDds* level:

$$ceiled\_\log\_tss_i = MIN(\log\_tss_i + PCBds, 0\,\text{dB})$$

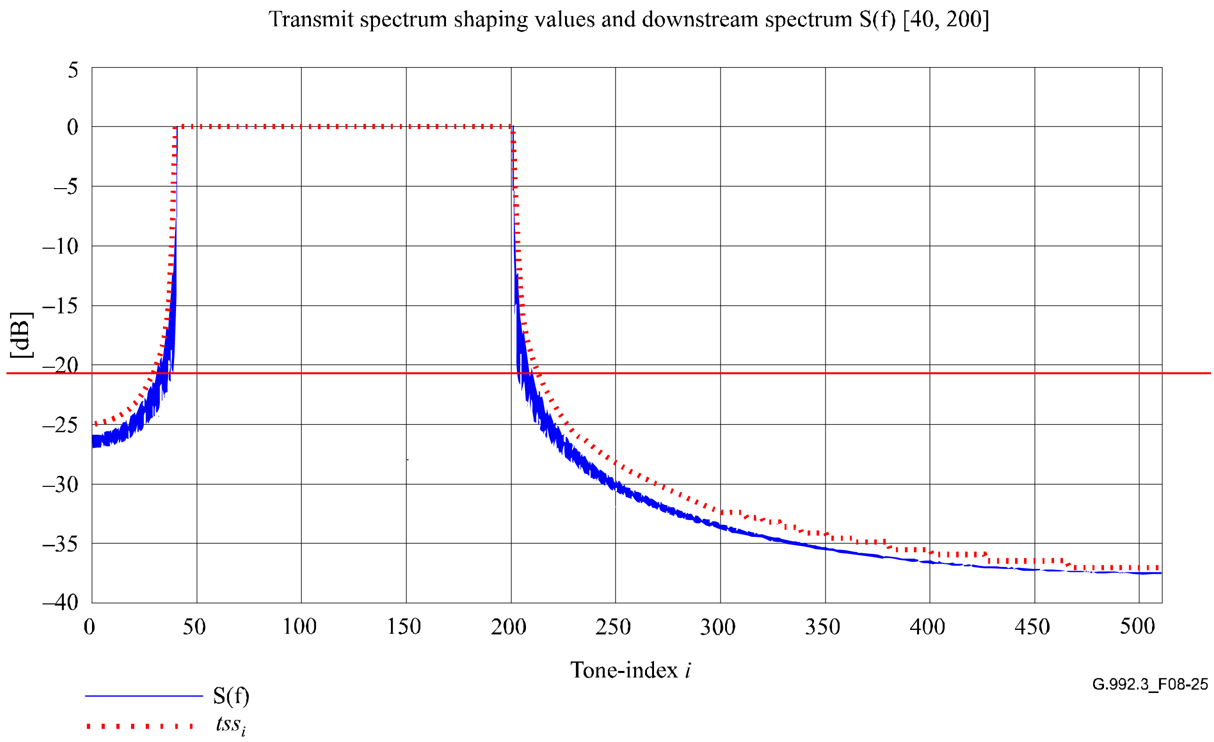
The $ceiled\_log\_tss_i$ shall only be computed at the beginning of the transceiver training phase and shall not be adapted when *PCBds* changes during showtime (e.g., with entry into the L2 power management state or with L2 trim, see clause 9.4.1.7).

– Starting from the transceiver training phase, tss_i values for subcarriers not included in the downstream SUPPORTEDset shall be applied as indicated in the ITU-T G.994.1 CL message, relative to the *REFPSDds* level.

NOTE 5 – This corresponds to a ceiling of the transmit PSD to the *REFPSDds* level over the subcarriers included in the SUPPORTEDset, and a lowering of the transmit PSD by *PCBds* dB over the subcarriers not included in the SUPPORTEDset. Depending on the spectrum shaping applied through the tss_i values as indicated in the ITU-T G.994.1 CL message, this may reduce the transmit PSD level only in a part or in the whole passband.

NOTE 6 – Because the ATU-C applies the downstream power cutback through a ceiling of the downstream tss_i values before being applied relative to the *REFPSDds* level. This implies that the ATU-R receiver will have to take into account the downstream tss_i values indicated in the ITU-T G.994.1 CL message when determining the downstream power cutback to be requested through the R-MSG-PCB message.

Figure 8-25 shows an example of the downstream tss_i values as a function of the subcarrier index i, for the case that the SUPPORTEDset contains the subcarriers with index ~~$i = 40$ to 200 and $N = 2 \times NSC = 512$~~ i = 100 to 399 and i = 484 to 500 and for $N = 2 \times NSC = 1024$ (oversampled IDFT). At frequencies $i \times \Delta f$, with ~~$40 \leq i \leq 200$~~ $100 \leq i \leq 399$ and $484 \leq i \leq 500$ and $\Delta f = 4.3125$ kHz, the tss_i value ~~equals 1 (0 dB)~~ is chosen such that for ideal filters, ideal DAC and ideal AFE, the spectrum on the U-interface corresponds with the transmit spectrum given in Annex A. At frequencies $i \times \Delta f$, with $400 \leq i \leq 483$ the carriers are not in the SUPPORTEDset to avoid the HAM-band [1.81, 2.0] MHz, taking into account a 20-tone transition band. In this case, no windowing is assumed and therefore some extra notch-filter needs to be applied to reach a stopband of –80 dBm/Hz.



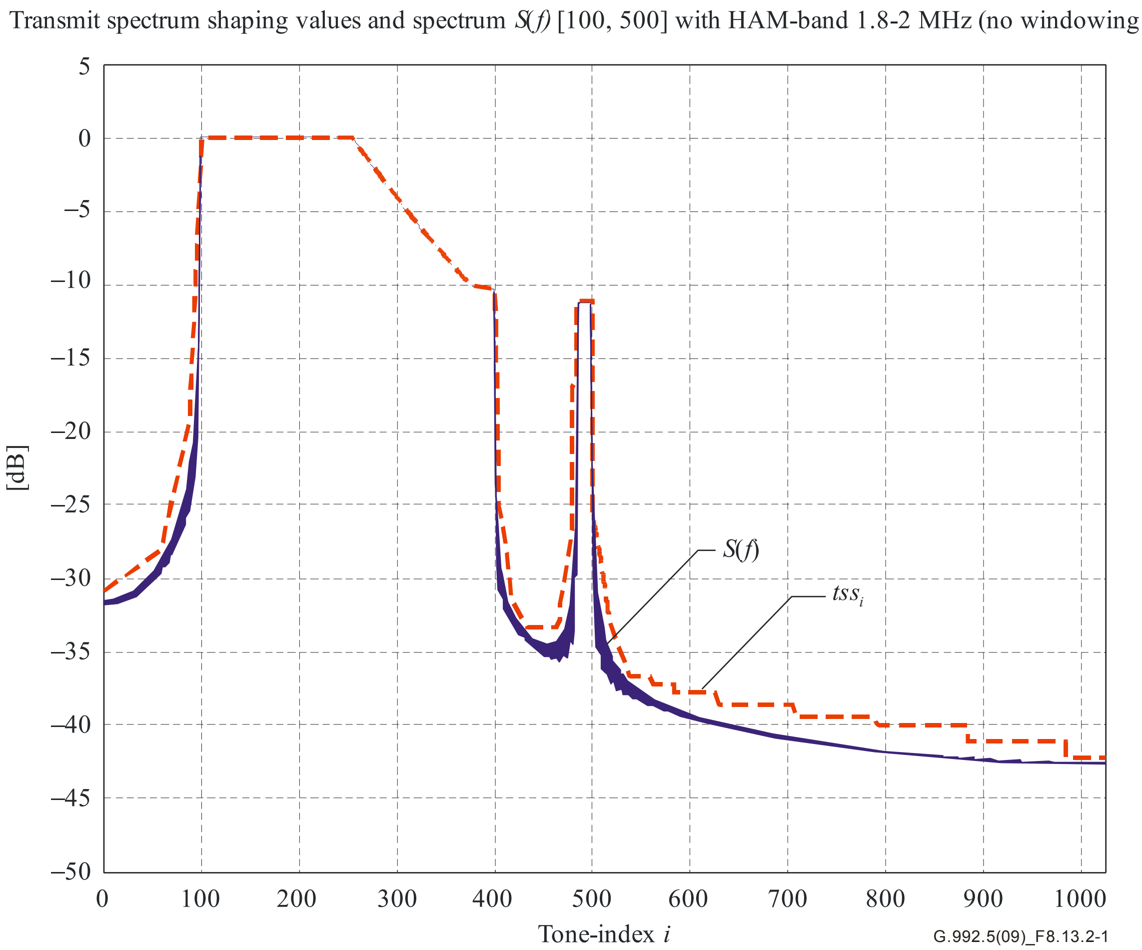


Figure 8-25 – Example of the downstream log_tss_i values (in dB) as a function of the subcarrier index

•••

NOTE ~~5~~ 7 – For the downstream direction, the CO-MIB contains a per-subcarrier indication of the maximum transmit PSD level at the U-C reference point, to apply at all times, except during the ITU-T G.994.1 phase. The CO-MIB also contains a per-subcarrier indication whether or not the subcarrier is allowed to be sent starting from the initialization channel analysis phase. From this information, and taking into account its own capabilities, the ATU-C selects the downstream SUPPORTEDset of subcarriers and computes the CL downstream spectrum shaping parameter block information.

NOTE ~~6~~ 8 – For the upstream direction, the CO-MIB contains a per-subcarrier indication whether or not the subcarrier is allowed to be sent starting from the initialization channel analysis phase. This information is conveyed to the ATU-R in the CL upstream spectrum shaping parameter block (through SUPPORTEDset indications and only using tss_i values 0 and 1 in linear scale). From this information, and taking into account its own capabilities, the ATU-R selects the upstream SUPPORTEDset of subcarriers and computes the CLR upstream spectrum shaping parameter block information.

NOTE ~~7~~ 9 – With the tss_i values contained in the different spectrum shaping blocks, the ATU indicates which subcarriers the ATU intends to transmit (subcarriers in the SUPPORTEDset) and which ones the ATU does not intend to transmit (subcarriers not in the SUPPORTEDset) during channel analysis for both the upstream and downstream directions. This is needed to make sure the ATU-R can select a C-TREF pilot tone which will be transmitted starting from the channel analysis phase. This also facilitates the selection by the PMD receive function of unused subcarriers for SNR monitoring and the selection of subcarriers to modulate the PARAMS messages.

•••

8.13.3 Channel discovery phase

See clause 8.13.3 of ITU-T G.992.3.

8.13.3.1 ATU-C channel discovery

See clause 8.13.3.1 of ITU-T G.992.3.

8.13.3.1.1 C-QUIET1

See clause 8.13.3.1.1 of ITU-T G.992.3.

8.13.3.1.2 C-COMB1

See clause 8.13.3.1.2 of ITU-T G.992.3, modified as follows.

The duration of the C-COMB1 state is of fixed length. In the C-COMB1 state, the ATU-C shall transmit 128 C-COMB symbols.

During this state, the ATU-R performs timing recovery and measures some characteristics of the downstream channel for C-TREF pilot tone selection and for the estimation of the required ATU-R minimum upstream power cutback and ATU-R minimum downstream power cutback. These functions can be continued during C-COMB2.

The C-COMB symbol shall be defined as a wideband multi-tone symbol containing the 16 subcarriers with index 11, 23, 35, 47, 59, 64, 71, 83, 95, 107, 119, 143, 179, 203, 227 and 251 and all subsequent subcarriers with index $251 + k \times 24$ (with k integer such that the subcarrier index is in the 256 to $NSCds - 1$ range). The subcarrier spacing has been selected to minimize audible interference into the POTS band prior to applying cutbacks that may be required in the presence of an off-hook POTS terminal and to limit aggregate transmit power to 8.4 dBm (i.e., the 12 dB power cutback level).

The subcarriers contained in the C-COMB symbol shall modulate the same data bits that are used for the C-REVERB symbols, in such a way that same subcarrier indices modulate the same data bits with the same 4-QAM constellation, as defined in clause 8.13.4.1.1. The subcarriers not contained in the C-COMB symbol shall be transmitted at no power (i.e., $X_i = Y_i = 0$).

The C-COMB1 state shall be followed by the C-QUIET2 state.

8.13.3.1.3 C-QUIET2

See clause 8.13.3.1.3 of ITU-T G.992.3.

8.13.3.1.4 C-COMB2

See clause 8.13.3.1.4 of ITU-T G.992.3.

8.13.3.1.5 C-ICOMB1

See clause 8.13.3.1.5 of ITU-T G.992.3.

8.13.3.1.6 C-LINEPROBE

See clause 8.13.3.1.6 of ITU-T G.992.3.

8.13.3.1.7 C-QUIET3

See clause 8.13.3.1.7 of ITU-T G.992.3.

8.13.3.1.8 C-COMB3

See clause 8.13.3.1.8 of ITU-T G.992.3.

8.13.3.1.9 C-ICOMB2

See clause 8.13.3.1.9 of ITU-T G.992.3.

8.13.3.1.10 C-MSG-FMT

See clause 8.13.3.1.10 of ITU-T G.992.3, modifying Table 8-26 as follows:

Table 8-26 – Bit definition for the C-MSG-FMT message

Bit index	Parameter	Definition
0	*FMT_R-REVERB1* (value 0 or 1)	Set to 1 indicates that the ATU-C requests an extended duration of the R-REVERB1 state. Set to 0 indicates it does not.
1		Reserved, set to 0.
2	*FMT_C-REVERB4* (value 0 or 1)	Set to 1 indicates that the ATU-C requests an extended duration of the C-REVERB4 state. Set to 0 indicates it does not.
7..3	*FMT_R-QUIET4* (value 0 to 31)	The (0 to 31) value mapped in these bits indicates the duration of the R-QUIET4 state. The MSB shall be mapped on the higher message bit index.
8	*FMT_C-MSG-PCB*	Set to 1 indicates that the C-MSG-PCB message shall include the C-BLACKOUT bits. Set to 0 indicates it shall not.
9	*FMT_C-MSG1*	Set to 1 indicates that windowing is applied with window samples included in the C-MSG1 message. Set to 0 indicates no windowing is applied and no window samples are included in C-MSG1 message.
10	*FMT-C-MEDLEYPRBS*	Set to 1 indicates that the ATU-C requests to use the higher order PRBS for the C-MEDLEY data pattern (see clause 8.13.5.1.4).
15..~~9~~11		Reserved, set to 0.

8.13.3.2 ATU-R channel discovery

See clause 8.13.3.2 of ITU-T G.992.3, modifying Tables 8-31 and 8-32 as follows:

Table 8-31 – Bit definition for the R-MSG-FMT message

Bit index	Parameter	Definition
0	*FMT-R-REVERB1* (value 0 or 1)	Set to 1 indicates that the ATU-R requests an extended duration of the R-REVERB1 state. Set to 0 indicates it does not.
1		Reserved, set to 0.
2	*FMT-C-REVERB4* (value 0 or 1)	Set to 1 indicates that the ATU-R requests an extended duration of the C-REVERB4 state. Set to 0 indicates it does not.
6..3	*FMT-C-TREF1* (value 1 to 15)	The value mapped in these bits indicates the minimum duration of the C-TREF1 state. The MSB shall be mapped on the higher message bit index.
7	*FMT-R-MSG-PCB* (value 0 or 1)	Set to 1 indicates that the R-MSG-PCB message shall include the R-BLACKOUT bits. Set to 0 indicates it shall not.
8	*FMT-C-TREF2* (value 0 or 1)	Indicates that the ATU-R requests the ATU-C to transmit C-TREF symbols (if set to 1) or C-QUIET symbols (if set to 0) during R-ECT.
9	*FMT-C-PILOT* (value 0 or 1)	Set to 1 indicates that the ATU-R requests the ATU-C to transmit a fixed 4-QAM constellation point on the C-TREF pilot tone. Set to 0 indicates it does not.
10	*FMT-C-MEDLEYPRBS*	Set to 1 indicates that the ATU-R requests to use the higher order PRBS for the C-MEDLEY data pattern (see clause 8.13.5.1.4).
15..~~10~~11		Reserved, set to 0.

Table 8-32 – Bit definition for the R-MSG-PCB message

Bit index	Parameter	Definition
5..0	*R-MIN_PCB_DS*	ATU-R minimum downstream power cutback (6-bit value with MSB in bit 5 and LSB in bit 0)
11..6	*R-MIN_PCB_US*	ATU-R minimum upstream power cutback (6-bit value with MSB in bit 11 and LSB in bit 6)
13..12	*HOOK_STATUS*	Hook status (2-bit value with MSB in bit 13 and LSB in bit 12)
15..14		Reserved, set to 0
~~23~~26..16	*C-PILOT*	Subcarrier index of downstream pilot tone (~~8~~11-bit value with MSB in bit ~~23~~26 and LSB in bit 16)
31..~~24~~27		Reserved, set to 0
31 + *NSCds*..32	*R-BLACKOUT*	Blackout indication per subcarrier (subcarrier *NSCds* – 1 in bit 31 + *NSCds*, subcarrier 0 in bit 32). Bit 32 shall be set to 0 (i.e., no blackout of DC subcarrier).

8.13.4 Transceiver training phase

See clause 8.13.4 of ITU-T G.992.3.

8.13.5 Channel analysis phase

See clause 8.13.5 of ITU-T G.992.3.

8.13.5.1 ATU-C channel analysis

See clause 8.13.5.1 of ITU-T G.992.3.

8.13.5.1.1 C-MSG1

See clause 8.13.5.1.1 of ITU-T G.992.3, modifying Table 8-37 as follows:

Table 8-37 – C-MSG1 prefix, message and CRC length

Part of message	Length (bits or symbols)
Prefix	32
Npmd (see Note)	160 or 160 + *NSCds*/4
Npms	32
Ntps	0
Nmsg	192 or 192 + *NSCds*/4
CRC	16
LEN_C-MSG1 (symbols)	240 or 240 + *NSCds*/4
NOTE – Length depends on whether or not windowing is applied (see clause 8.5.3.2).	

8.13.5.1.2 C-REVERB5

See clause 8.13.5.1.2 of ITU-T G.992.3.

8.13.5.1.3 C-SEGUE2

See clause 8.13.5.1.3 of ITU-T G.992.3.

8.13.5.1.4 C-MEDLEY

See clause 8.13.5.1.4 of ITU-T G.992.3, modified as follows.

The C-MEDLEY state is of fixed length. In this state, the ATU-C shall transmit *LEN_MEDLEY* symbols. The value *LEN_MEDLEY* shall be the maximum of the *CA-MEDLEYus* and *CA-MEDLEYds* values indicated by the ATU-C and the ATU-R in the C-MSG1 and R-MSG1 messages respectively. The value *LEN_MEDLEY* shall be a multiple of 512 and shall be less than or equal to 32256. The number of symbols transmitted in the C-MEDLEY state shall be equal to the number of symbols transmitted by the ATU-R in the R-MEDLEY state.

A C-MEDLEY symbol shall be defined depending on its symbolcount within the C-MEDLEY state. The first symbol transmitted in the C-MEDLEY state shall have symbolcount equal to zero. For each symbol transmitted in the C-MEDLEY state, the symbolcount shall be incremented.

The data pattern modulated onto each C-MEDLEY symbol shall be taken from the pseudo-random binary sequence (PRBS) defined by:

$$d_n = 1 \text{ for } n = 1 \text{ to } 9 \text{ and } \qquad d_n = d_{n-4} \oplus d_{n-9} \text{ for } n > 9$$

or:

$$d_n = 1 \text{ for } n = 1 \text{ to } 14 \text{ and } d_n = d_{n-5} \oplus d_{n-11} \oplus d_{n-12} \oplus d_{n-14} \text{ for } n > 14$$

Support of the fourteenth order PRBS is optional for the ATU-C and ATU-R. The 14th order PRBS shall be used if, and only if, the FMT-C-MEDLEYPRBS bit is set to 1 in both the C-MSG-FMT and R-MSG-FMT message, respectively. The ninth order polynomial shall be used otherwise.

The C-MEDLEY symbol with symbolcount i shall modulate the ~~512 bits $d_{512\times i+1}$ to $d_{512\times(i+1)}$~~ 2 × *NSCds* bits $d_{2 \times NSCds \times i + 1}$ to $d_{2 \times NSCds \times (i + 1)}$.

Bits shall be extracted from the PRBS in pairs. For each symbol transmitted in the C-MEDLEY state, ~~256~~*NSCds* pairs (~~512~~2 × *NSCds* bits) shall be extracted from the PRBS generator. The first extracted pair shall be modulated onto subcarrier 0 (so the bits are effectively ignored). The subsequent pairs are used to define the X_i and Y_i components for the subcarriers $i = 1$

to *NSCds* – 1, as defined in Table 8-36 for C-REVERB symbols. For the subcarriers $i = NSCds$ to $2 \times NSCds - 1$, the $X_i = Y_i = 0$.

~~NOTE – 256 bit pairs per symbol are extracted from the PRBS. If *NSCds* is less than 256 (as in [b-ITU-T G.992.4]), then the last (256 – *NSCds*) bit pairs are effectively ignored.~~

While the ATU-C is in the C-MEDLEY state, the ATU-C and ATU-R may perform further training and SNR estimation.

The C-MEDLEY state shall be followed by the C-EXCHMARKER state.

8.13.6 Exchange phase

8.13.6.1 ATU-C exchange phase

See clause 8.13.6.1 of ITU-T G.992.3.

8.13.6.1.1 C-MSG2

See clause 8.13.6.1.1 of ITU-T G.992.3.

8.13.6.1.2 C-REVERB6

See clause 8.13.6.1.2 of ITU-T G.992.3, modifying the first paragraph as follows:

The C-REVERB6 state is of variable length. In this state, the ATU-C shall transmit a minimum of ~~(246 – *NSCus*)~~MAX(*NSCds* – *NSCus* – 10, 80) and a maximum of ~~(2246 – *NSCus*)~~MAX(*NSCds* – *NSCus* + 1990, 2000) C-REVERB symbols.

8.13.6.1.3 C-SEGUE3

See clause 8.13.6.1.3 of ITU-T G.992.3.

8.13.6.1.4 C-PARAMS

See clause 8.13.6.1.4 of ITU-T G.992.3, modifying Table 8-39 as follows:

Table 8-39 – C-PARAMS message and CRC length

Part of message	Length (bits or symbols)
Npmd	96 + 24 × *NSCus*
Npms	224
Ntps	0
Nmsg	320 + ~~24~~32 × *NSCus*
CRC	16
LEN_C-PARAMS (state length in symbols)	~~$\left\lceil \frac{336 + 24 \times NSCus}{2 \times NSC\_C\text{-}PARAMS} \right\rceil$~~ $\left\lceil \frac{336 + 32 \times NSCus}{2 \times NSC\_C\text{-}PARAMS} \right\rceil$
NOTE – $\lceil x \rceil$ denotes rounding to the higher integer.	

8.13.6.2 ATU-R exchange phase

See clause 8.13.6.2 of ITU-T G.992.3.

8.13.6.2.1 R-MSG2

See clause 8.13.6.2.1 of ITU-T G.992.3, modified as follows.

The R-MSG2 state is of fixed length. In the R-MSG2 state, the ATU-R shall transmit ~~272~~*NSCds* + 16 R-REVERB or R-SEGUE symbols to modulate the R-MSG2 message and CRC.

The R-MSG2 message *m* is defined by:

$$m = \{\sout{m_{225}}\, m_{NSCds-1}, \ldots, m_0\}$$

The bit m_i shall be set to 1 to indicate that the ATU-C shall use subcarrier index *i* to modulate the C-PARAMS message. The bit m_i shall be set to 0 to indicate that the ATU-C shall not use subcarrier index *i* to modulate the C-PARAMS message. At least 4 subcarriers shall be used for modulation of the C-PARAMS message. The C-PARAMS message will be transmitted at about 8 kbit/s times the number of subcarriers used for modulation of the message.

~~NOTE – The R-MSG2 message length is 256 bits (1 bit per subcarrier). If *NSCds* is less than 256 (as in [b-ITU-T G.992.4]), then the last (256 – *NSCds*) bits m_{255} to m_{NSCds} are set to 0.~~

If the ATU-R has set the R-MSG-FMT message bit FMT-C-PILOT to 1, then the ATU-C modulates the C-TREF pilot tone with a fixed constellation point. In this case, the ATU-R shall not use the C-TREF pilot tone for modulation of the C-PARAMS message.

The bits ~~m_0-m_{255}~~m_0-$m_{NSCds-1}$ shall be transmitted in ~~256~~*NSCds* symbol periods (m_0 first and ~~m_{255}~~$m_{NSCds-1}$ last). A zero bit shall be transmitted as an R-REVERB symbol. A one bit shall be transmitted as an R-SEGUE symbol.

After the R-MSG2 message has been transmitted, a CRC shall be appended to the message. The 16 CRC bits shall be computed from the ~~256~~*NSCds* message *m* bits in the same way as the CRC bits are calculated for the C-MSG-PCB message.

The 16 bits c_0-c_{15} shall be transmitted in 16 symbol periods (c_0 first and c_{15} last) using the same modulation as used to transmit the message *m*.

If the ATU-R has transmitted R-REVERB symbols during the R-EXCHMARKER state, the R-MSG2 state shall be followed by the R-REVERB6 state. If the ATU-R has transmitted R-SEGUE symbols during the R-EXCHMARKER state, the R-MSG2 state shall be followed by the R-REVERB7 state.

8.13.6.2.2 R-REVERB6

See clause 8.13.6.2.2 of ITU-T G.992.3.

8.13.6.2.3 R-SEGUE3

See clause 8.13.6.2.3 of ITU-T G.992.3.

8.13.6.2.4 R-PARAMS

See clause 8.13.6.2.4 of ITU-T G.992.3, modifying Table 8-40 as follows:

Table 8-40 – R-PARAMS message and CRC length

Part of message	Length in bits
Npmd	96 + 24 × *NSCds*
Npms	224
Ntps	0
Nmsg	320 + ~~24~~32 × *NSCds*
CRC	16
LEN_R-PARAMS (state length in symbols)	~~$\left\lceil \frac{336 + 24 \times NSCds}{2 \times NSC\_R\text{-}PARAMS} \right\rceil$~~ $\left\lceil \frac{336 + 32 \times NSCds}{2 \times NSC\_R-PARAMS} \right\rceil$
NOTE – $\lceil x \rceil$ denotes rounding to the higher integer.	

8.13.7 Timing diagram of the initialization procedures

See clause 8.13.7 of ITU-T G.992.3, replacing Figures 8-27 to 8-30 with the following:

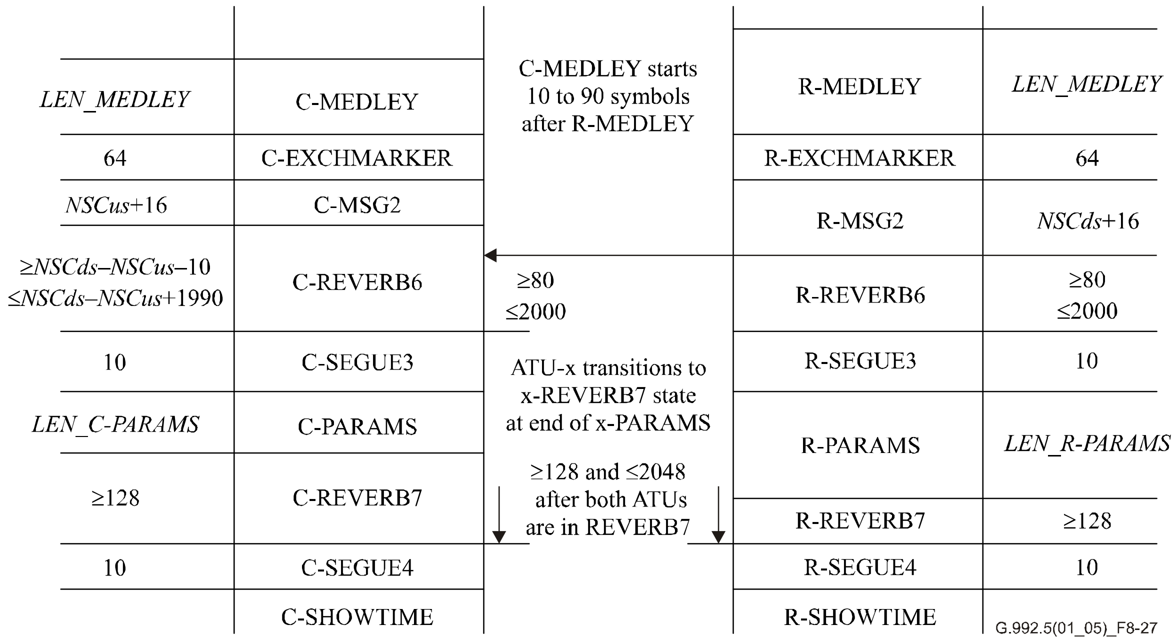


Figure 8-27 – Timing diagram of the initialization procedure (part 2) with C-PARAMS and with R-PARAMS states

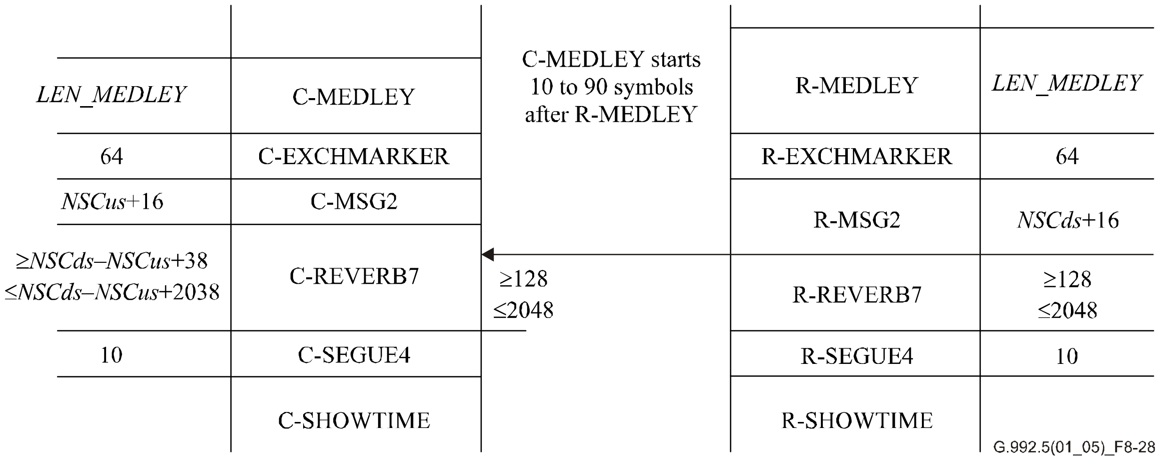


Figure 8-28 – Timing diagram of the initialization procedure (part 2) without C-PARAMS and without R-PARAMS states

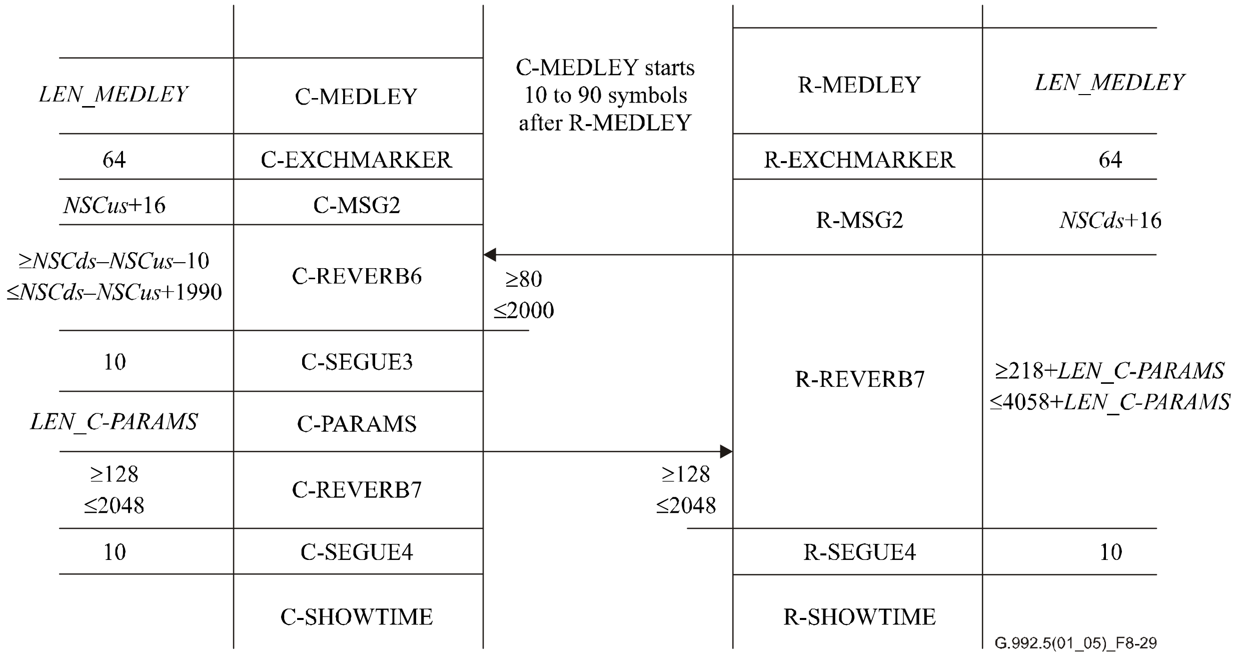


Figure 8-29 – Timing diagram of the initialization procedure (part 2) with C-PARAMS and without R-PARAMS states

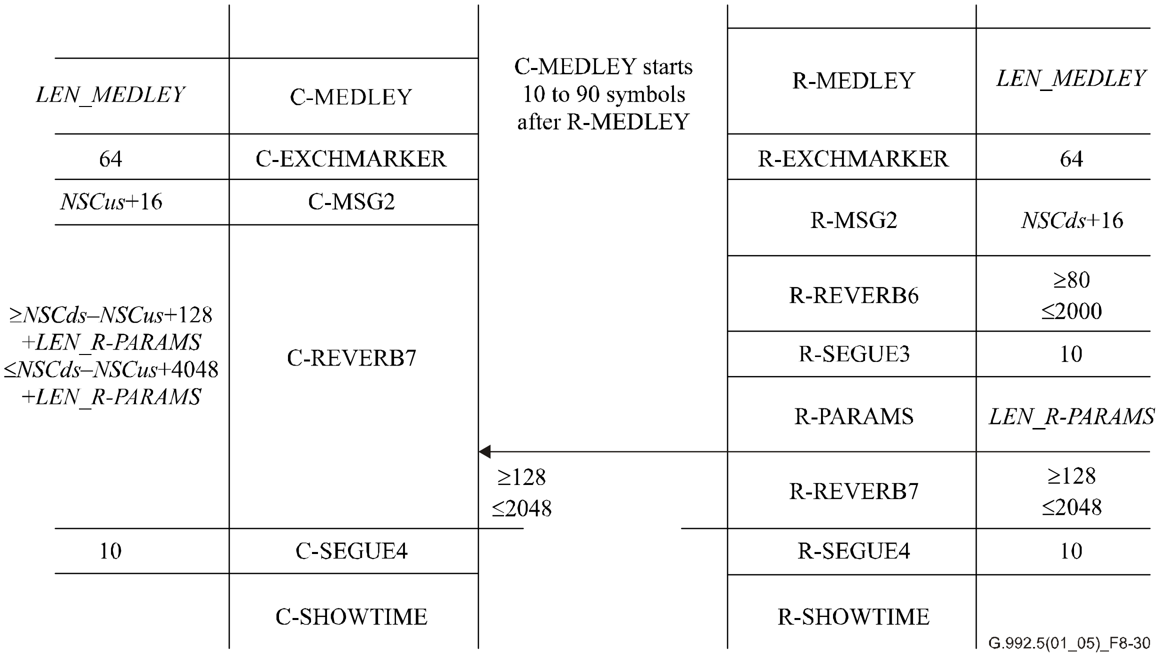


Figure 8-30 – Timing diagram of the initialization procedure (part 2) without C-PARAMS and with R-PARAMS states

8.14 Short initialization procedures

See clause 8.14 of ITU-T G.992.3, replacing Figure 8-34 with the following:

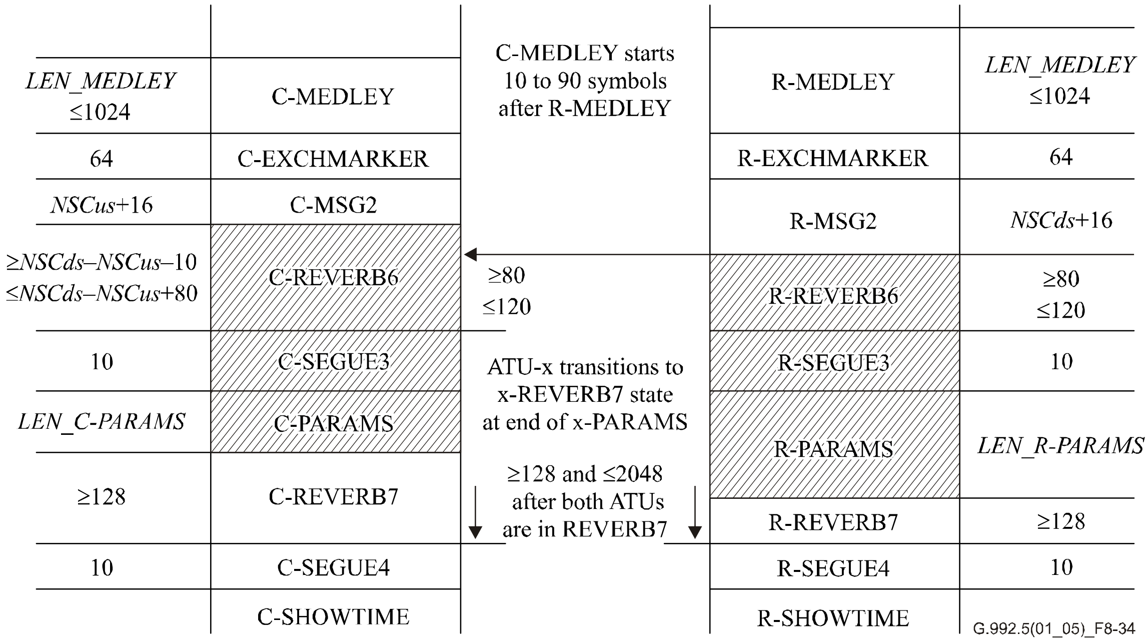


Figure 8-34 – Timing diagram of the short initialization procedure (part 2)

8.15 Loop diagnostics mode procedures

See clause 8.15 of ITU-T G.992.3.

8.15.1 Overview

See clause 8.15.1 of ITU-T G.992.3.

8.15.2 Channel discovery phase

8.15.2.1 ATU-C channel discovery phase

See clause 8.15.2.1 of ITU-T G.992.3, modifying Table 8-43 as follows:

Table 8-43 – Bit definition for the C-MSG-FMT message

Bit index	Parameter	Definition
9..0		Reserved, set to 0
10	*FMT-C-MEDLEYPRBS*	See Table 8-26
15 .. ~~0~~11		Reserved, set to 0

8.15.2.2 ATU-R channel discovery phase

See clause 8.15.2.2 of ITU-T G.992.3, modifying Tables 8-46 and 8-47 as follows:

Table 8-46 – Bit definition for the R-MSG-FMT message

Bit index	Parameter	Definition
7..0		Reserved, set to 0
8	*FMT-C-TREF2*	See Table 8-31
9	*FMT-C-PILOT*	See Table 8-31
10	*FMT-C-MEDLEYPRBS*	See Table 8-31
15..~~10~~11		Reserved, set to 0

Table 8-47 – Bit definition for the R-MSG-PCB message

Bit index	Parameter	Definition
5..0	*R-MIN_PCB_DS*	See Table 8-32
11..6	*R-MIN_PCB_US*	See Table 8-32
13..12	*HOOK_STATUS*	See Table 8-32
15..14		Reserved, set to 0
~~23~~26..16	*C-PILOT*	See Table 8-32
31..~~24~~27		Reserved, set to 0
31 + *NSCds*..32	*R-BLACKOUT*	See Table 8-32
~~287..32 + *NSCds*~~		~~Reserved, set to 0 (see Note)~~
~~295..288~~ 39 + *NSCds*..32 + *NSCds*	Pass/fail	Success or failure cause indication of last previous initialization
~~303..296~~ 47 + *NSCds*..40 + *NSCds*	*Last_TX_State*	Last transmitted state of last previous initialization
~~NOTE – These reserved bits are present only if *NSCds* < 256 (as in [b-ITU-T G.992.4]).~~		

8.15.3 Transceiver training phase

See clause 8.15.3 of ITU-T G.992.3.

8.15.4 Channel analysis phase

See clause 8.15.4 of ITU-T G.992.3.

8.15.5 Exchange phase

See clause 8.15.5 of ITU-T G.992.3.

8.15.5.1 ATU-C exchange phase

See clause 8.15.5.1 of ITU-T G.992.3.

8.15.5.2 ATU-R exchange phase

See clause 8.15.5.2 of ITU-T G.992.3.

8.15.5.2.1 Channel information bearing messages

See clause 8.15.5.2.1 of ITU-T G.992.3, modified as follows:

In the loop diagnostics mode, the ATU-R shall send ~~nine~~ (1 + *NSCds*/32) messages to the ATU-C: ~~R-MSG1-LD to R-MSG9-LD~~ R-MSGx-LD, numbered from $x = 1$ to $1 + NSCds/32$. These messages contain the downstream test parameters defined in clause 8.15.1.

The information fields of the different messages shall be as shown in Tables 8-55 to 8-63.

Table 8-55 – Format of the R-MSG1-LD message

Octet Nr [i]	Information	Format message bits [8 × i + 7 to 8 × i + 0]
0	Sequence number	[~~0001~~0000 0001]
1	Reserved	[0000 0000]
2	Hlin scale (LSB)	[xxxx xxxx], bit 7 to 0
3	Hlin scale (MSB)	[xxxx xxxx], bit 15 to 8
4	*LATN* (LSB)	[xxxx xxxx], bit 7 to 0
5	*LATN* (MSB)	[0000 00xx], bit 9 and 8
6	*SATN* (LSB)	[xxxx xxxx], bit 7 to 0
7	*SATN* (MSB)	[0000 00xx], bit 9 and 8
8	*SNRM* (LSB)	[xxxx xxxx], bit 7 to 0
9	*SNRM* (MSB)	[0000 00xx], bit 9 and 8
10	*ATTNDR* (LSB)	[xxxx xxxx], bit 7 to 0
11	*ATTNDR*	[xxxx xxxx], bit 15 to 8
12	*ATTNDR*	[xxxx xxxx], bit 23 to 16
13	*ATTNDR* (MSB)	[xxxx xxxx], bit 31 to 24
14	Far-end *ACTATP* (LSB)	[xxxx xxxx], bit 7 to 0
15	Far-end *ACTATP* (MSB)	[ssss ssxx], bit 9 and 8

Table 8-56/57/58/59 – Format of the Hlin(i) R-MSG~~2~~x-LD message

Octet Nr [i]	Information	Format message bits [8 × i + 7 to 8 × i + 0]
0	Sequence number	~~[0010 0010]~~ [xxxx xxxx] (as 8-bit unsigned integer)

Octet Nr [i]	Information	Format message bits [8 × i + 7 to 8 × i + 0]
1	Reserved	[0000 0000]
2	Hlin(~~0~~$64 \times k$) real (LSB)	[xxxx xxxx], bit 7 to 0
3	Hlin(~~0~~$64 \times k$) real (MSB)	[xxxx xxxx], bit 15 to 8
4	Hlin(~~0~~$64 \times k$) imag (LSB)	[xxxx xxxx], bit 7 to 0
5	Hlin(~~0~~$64 \times k$) imag (MSB)	[xxxx xxxx], bit 15 to 8
…..	…..	…..
254	Hlin($64 \times k + 63$) real (LSB)	[xxxx xxxx], bit 7 to 0
255	Hlin($64 \times k + 63$) real (MSB)	[xxxx xxxx], bit 15 to 8
256	Hlin($64 \times k + 63$) imag (LSB)	[xxxx xxxx], bit 7 to 0
257	Hlin($64 \times k + 63$) imag (MSB)	[xxxx xxxx], bit 15 to 8
NOTE – For each of the values $k = 0$ to $NSCds/64 - 1$, a single R-MSGx-LD message shall be transmitted, with sequence number $x = 2 + k$.		

~~**Table 8-57 – Format of the R-MSG3-LD message**~~

~~Octet Nr [i]~~	~~Information~~	~~Format message bits [8 × i + 7 to 8 × i + 0]~~
~~0~~	~~Sequence number~~	~~[0011 0011]~~
~~1~~	~~Reserved~~	~~[0000 0000]~~
~~2~~	~~Hlin(64) real (LSB)~~	~~[xxxx xxxx], bit 7 to 0~~
~~3~~	~~Hlin(64) real (MSB)~~	~~[xxxx xxxx], bit 15 to 8~~
~~4~~	~~Hlin(64) imag (LSB)~~	~~[xxxx xxxx], bit 7 to 0~~
~~5~~	~~Hlin(64) imag (MSB)~~	~~[xxxx xxxx], bit 15 to 8~~
~~…..~~	~~…..~~	~~…..~~
~~254~~	~~Hlin(127) real (LSB)~~	~~[xxxx xxxx], bit 7 to 0~~
~~255~~	~~Hlin(127) real (MSB)~~	~~[xxxx xxxx], bit 15 to 8~~
~~256~~	~~Hlin(127) imag (LSB)~~	~~[xxxx xxxx], bit 7 to 0~~
~~257~~	~~Hlin(127) imag (MSB)~~	~~[xxxx xxxx], bit 15 to 8~~

~~**Table 8-58 – Format of the R-MSG4-LD message**~~

~~Octet Nr [i]~~	~~Information~~	~~Format message bits [8 × i + 7 to 8 × i + 0]~~
~~0~~	~~Sequence number~~	~~[0100 0100]~~
~~1~~	~~Reserved~~	~~[0000 0000]~~
~~2~~	~~Hlin(128) real (LSB)~~	~~[xxxx xxxx], bit 7 to 0~~
~~3~~	~~Hlin(128) real (MSB)~~	~~[xxxx xxxx], bit 15 to 8~~
~~4~~	~~Hlin(128) imag (LSB)~~	~~[xxxx xxxx], bit 7 to 0~~
~~5~~	~~Hlin(128) imag (MSB)~~	~~[xxxx xxxx], bit 15 to 8~~
~~…..~~	~~…..~~	~~…..~~
~~254~~	~~Hlin(191) real (LSB)~~	~~[xxxx xxxx], bit 7 to 0~~

Octet Nr [i]	Information	Format message bits [8 × i + 7 to 8 × i + 0]
255	Hlin(191) real (MSB)	[xxxx xxxx], bit 15 to 8
256	Hlin(191) imag (LSB)	[xxxx xxxx], bit 7 to 0
257	Hlin(191) imag (MSB)	[xxxx xxxx], bit 15 to 8

Table 8-59 – Format of the R-MSG5-LD message

Octet Nr [i]	Information	Format message bits [8 × i + 7 to 8 × i + 0]
0	Sequence number	[0101 0101]
1	Reserved	[0000 0000]
2	Hlin(192) real (LSB)	[xxxx xxxx], bit 7 to 0
3	Hlin(192) real (MSB)	[xxxx xxxx], bit 15 to 8
4	Hlin(192) imag (LSB)	[xxxx xxxx], bit 7 to 0
5	Hlin(192) imag (MSB)	[xxxx xxxx], bit 15 to 8
…..	…..	…..
254	Hlin(255) real (LSB)	[xxxx xxxx], bit 7 to 0
255	Hlin(255) real (MSB)	[xxxx xxxx], bit 15 to 8
256	Hlin(255) imag (LSB)	[xxxx xxxx], bit 7 to 0
257	Hlin(255) imag (MSB)	[xxxx xxxx], bit 15 to 8

Table 8-60/61 – Format of the Hlog(i) R-MSG6x-LD message

Octet Nr [i]	Information	Format message bits [8 × i + 7 to 8 × i + 0]
0	Sequence number	[0110 0110] [xxxx xxxx] (as 8-bit unsigned integer)
1	Reserved	[0000 0000]
2	Hlog(0128 × k) (LSB)	[xxxx xxxx], bit 7 to 0
3	Hlog(0128 × k) (MSB)	[0000 00xx], bit 9 and 8
…..	…..	…..
256	Hlog(128 × k + 127) (LSB)	[xxxx xxxx], bit 7 to 0
257	Hlog(128 × k + 127) (MSB)	[0000 00xx], bit 9 and 8
NOTE – For each of the values k = 0 to $NSCds$/128 – 1, a single R-MSGx-LD message shall be transmitted, with sequence number x = $NSCds$/64 + 2 + k.		

~~**Table 8-61 – Format of the R-MSG7-LD message**~~

~~Octet Nr [i]~~	~~Information~~	~~Format message bits [8 × i + 7 to 8 × i + 0]~~
~~0~~	~~Sequence number~~	~~[0111 0111]~~
~~1~~	~~Reserved~~	~~[0000 0000]~~
~~2~~	~~Hlog(128) (LSB)~~	~~[xxxx xxxx], bit 7 to 0~~
~~3~~	~~Hlog(128) (MSB)~~	~~[0000 00xx], bit 9 and 8~~
~~…..~~	~~…..~~	~~…..~~
~~256~~	~~Hlog(255) (LSB)~~	~~[xxxx xxxx], bit 7 to 0~~
~~257~~	~~Hlog(255) (MSB)~~	~~[0000 00xx], bit 9 and 8~~

Table 8-62 – Format of the QLN(i) R-MSG~~8~~x-LD message

Octet Nr [i]	Information	Format message bits [8 × i + 7 to 8 × i + 0]
0	Sequence number	~~[1000 1000]~~ [xxxx xxxx] (as 8-bit unsigned integer)
1	Reserved	[0000 0000]
2	QLN(~~0~~256 × *k*)	[xxxx xxxx], bit 7 to 0
…..	…..	…..
257	QLN(256 × *k* + 255)	[xxxx xxxx], bit 7 to 0
NOTE – For each of the values $k = 0$ to $NSCds/256 - 1$, a single R-MSGx-LD message shall be transmitted, with sequence number $x = 3 \times NSCds/128 + 2 + k$.		

Table 8-63 – Format of the SNR(i) R-MSG~~9~~x-LD message

Octet Nr [i]	Information	Format message bits [8 × i + 7 to 8 × i + 0]
0	Sequence number	~~[1001 1001]~~ [xxxx xxxx] (as 8-bit unsigned integer)
1	Reserved	[0000 0000]
2	SNR(~~0~~256 × *k*)	[xxxx xxxx], bit 7 to 0
…..	…..	…..
257	SNR(256 × *k* + 255)	[xxxx xxxx], bit 7 to 0
~~NOTE – In the case where the *NSCds* < 256 (as in [b-ITU-T G.992.4]), all line diagnostics messages are transmitted. However, in the messages carrying per-subcarrier information, the special value defined in clause 8.12.3 may be used to indicate that no measurement could be done for this subcarrier because it is out of the PSD mask passband.~~ NOTE – For each of the values $k = 0$ to $NSCds/256 - 1$, a single R-MSGx-LD message shall be transmitted, with sequence number $x = 7 \times NSCds/256 + 2 + k$.		

The messages shall be transmitted in order of ascending octet number (i.e., the sequence number shall be transmitted first) and each octet shall be transmitted LSB first.

The addition of a 16-bit CRC and the bit transmission order for the R-MSGx-LD messages shall be as defined for the initialization sequence in clause 8.13. However, the message and CRC bits shall be transmitted with an 8 symbols per bit modulation, where a zero bit shall be transmitted as eight consecutive R-REVERB symbols and a one bit shall be transmitted as eight consecutive R-SEGUE symbols. The resulting state duration (needed to transmit the message and CRC) is shown in Table 8-64.

Table 8-64 –ATU-R loop diagnostics state durations

State	Duration (symbols)
R-MSG1-LD	1152
R-MSGx-LD with $x > 1$	16640
R-MSG2-LD	16640
R-MSG3-LD	16640
R-MSG4-LD	16640
R-MSG5-LD	16640
R-MSG6-LD	16640
R-MSG7-LD	16640
R-MSG8-LD	16640
R-MSG9-LD	16640

The resulting number of symbols needed to transmit each of the messages and CRC is shown in the loop diagnostics timing diagrams in Figures 8-35 and 8-36.

8.15.5.2.2 Message flow, acknowledgement and retransmission

See clause 8.15.5.2.2 of ITU-T G.992.3.

8.15.6 Timing diagram of the loop diagnostics procedures

See clause 8.15.6 of ITU-T G.992.3, modified as follows:

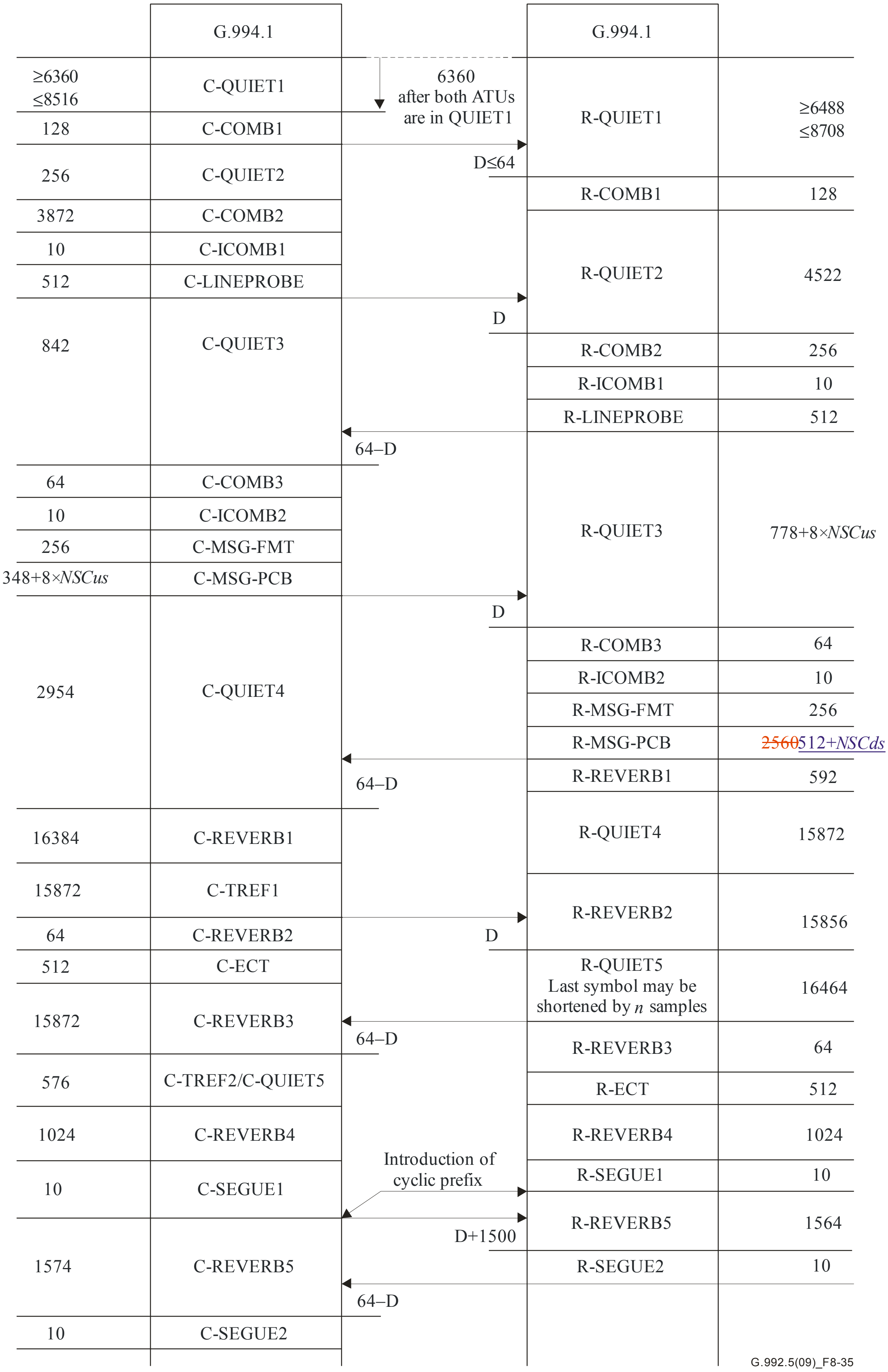


Figure 8-35 – Loop diagnostics timing diagram (part 1)

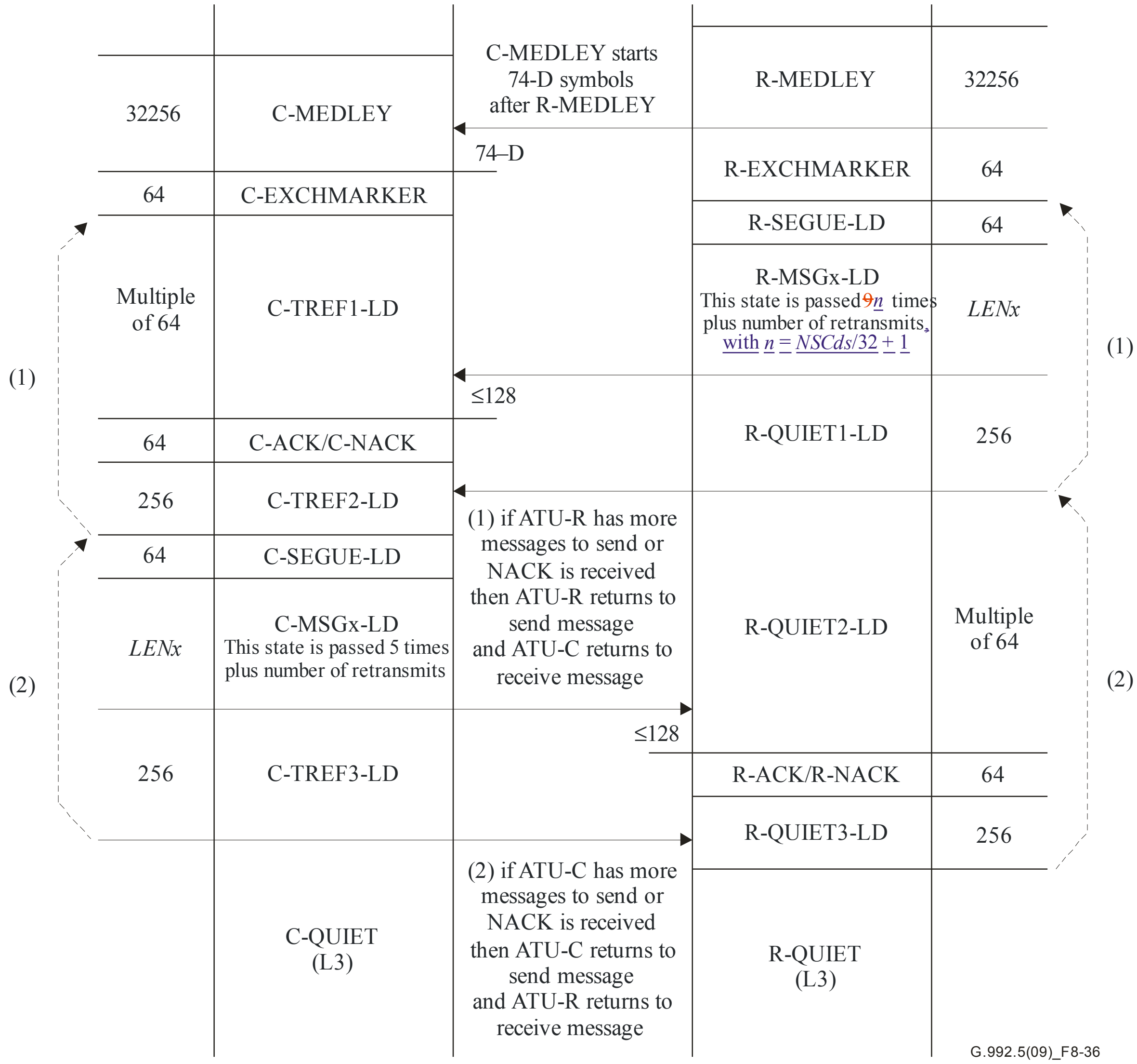


Figure 8-36 – Loop diagnostics timing diagram (part 2)

8.16 On-line reconfiguration of the PMD function

See clause 8.16 of ITU-T G.992.3.

8.17 Power management in the PMD function

See clause 8.17 of ITU-T G.992.3.

9 Management protocol-specific transmission convergence (MPS-TC) functions

See clause 9 of ITU-T G.992.3.

9.1 Transport functions

See clause 9.1 of ITU-T G.992.3.

9.2 Additional functions

See clause 9.2 of ITU-T G.992.3.

9.3 Block interface signals and primitives

See clause 9.3 of ITU-T G.992.3.

9.4 Management plane procedures

See clause 9.4 of ITU-T G.992.3.

9.4.1 Commands

See clause 9.4.1 of ITU-T G.992.3.

9.4.1.1 On-line reconfiguration command

See clause 9.4.1.1 of ITU-T G.992.3, modifying Table 9-7 and the text immediately after Table 9-8 as follows:

Table 9-7 – On-line reconfiguration commands transmitted by the initiating receiver

Message length (octets)	Element name (command)
~~3 + 3~~4 + 4 × N_f	01_{16} Request type 1 followed by: ~~1 octet~~2 octets for the number of subcarriers N_f ~~3~~4 × N_f octets describing subcarrier parameter field for each subcarrier
~~3~~4 + 2 × N_{LP} + N_{BC} + ~~3~~4 × N_f	02_{16} Request type 2 followed by: 2 × N_{LP} octets containing new L_p values for the N_{LP}-enabled latency paths, N_{BC} octets containing new $B_{p,n}$ values for the N_{BC}-enabled frame bearers, ~~1 octet~~2 octets for the number of carriers N_f ~~3~~4 × N_f octets describing subcarrier parameter field for each subcarrier
~~3~~4 + 2 × N_{LP} + N_{BC} + ~~3~~4 × N_f	03_{16} Request type 3 followed by: 2 × N_{LP} octets containing new L_p values for the N_{LP}-enabled latency paths, N_{BC} octets containing new $B_{p,n}$ values for the N_{BC}-enabled frame bearers, ~~1 octet~~2 octets for the number of carriers N_f ~~3~~4 × N_f octets describing subcarrier parameter field for each subcarrier All other octet values are reserved by ITU-T.

• • •

A subcarrier parameter field contains ~~3 octets~~4 octets formatted as [cccc cccc gggg gggg gggg bbbb]. The carrier index i (~~8~~11 bits), the g_i (12 bits) and the b_i (4 bits). The carrier index shall be the three least significant bits of the first octet and the second octet of the subcarrier field. The least significant bits of the carrier index i shall be contained in the second octet. The g_i shall be contained in the ~~second~~third octet and the four most significant bits of the ~~third~~fourth octet. The least significant bits of g_i shall be contained in the ~~third~~fourth octet. The b_i shall be the least significant 4 bits of the ~~third~~fourth octet.

• • •

9.4.1.2 eoc commands

See clause 9.4.1.2 of ITU-T G.992.3.

9.4.1.3 Time commands

See clause 9.4.1.3 of ITU-T G.992.3.

9.4.1.4 Inventory command

See clause 9.4.1.4 of ITU-T G.992.3.

9.4.1.5 Control value read commands

See clause 9.4.1.5 of ITU-T G.992.3.

9.4.1.6 Management counter read commands

See clause 9.4.1.6 of ITU-T G.992.3.

9.4.1.7 Power management commands

See clause 9.4.1.7 of ITU-T G.992.3, modifying the following text immediately after Table 9-22:

In the L2 request, L2 grant, L2 trim request and L2 trim grant messages, power cutback values shall be expressed as an absolute power cutback in the range of 0 to 40 dB in steps of 1 dB. The cutback is defined in terms of *PCBds*. The minimum and maximum requested values are defined in absolute terms and not relative to the current *PCBds* value. Values not inclusively within the range of the *PCBds* determined during initialization to 40 dB shall not be encoded. It is intended that up to 40 dB of absolute power cutback can be performed for the L2 link state using the *PCBds* control parameter and that the gain values can be used to additionally adjust the gain per carrier as required. The extra power cutback applied during the L2 state (i.e., *PCBds*(L2) – *PCBds*(init)) shall be applied as a flat cutback (i.e., each subcarrier is reduced by the same amount) relative to the L0 transmit PSD level (i.e., relative to the *REFPSDds*(init) transmit PSD level, adjusted by the $ceiled\_log\_tss_i$ values as determined and applied during transceiver training).

9.4.1.8 Clear eoc messages

See clause 9.4.1.8 of ITU-T G.992.3.

9.4.1.9 Non-standard facility overhead commands

See clause 9.4.1.9 of ITU-T G.992.3.

9.4.1.10 Test parameter messages

See clause 9.4.1.10 of ITU-T G.992.3, modifying the first paragraph and Table 9-28 as follows:

The PMD test parameters read commands shall be used to access the value of certain PMD test parameters maintained by the far ATU in accordance with the description of the PMD function. The local parameter values shall be retrieved as described in this clause. The PMD test parameter read command may be initiated by either ATU as shown in Table 9-28. The responses shall be using the command shown in Table 9-29. The PMD test parameter read command shall consist of two to ~~four~~six octets. The first octet shall be the PMD test parameter command designator shown in Table 9-4. The remaining octets shall be as shown in Table 9-28. The PMD test parameter read response command shall be multiple octets. The first octet shall be PMD test parameter read command designator shown in Table 9-4. ~~The second shall correspond to the received PMD test parameter read command second octet, XOR 80_{16}, except for the next multiple read command (see Tables 9-28 and 9-29).~~ The remaining octets shall be as shown in Table 9-29. The octets shall be sent using the format described in clause 7.8.2.3 and using the protocol described in clause 7.8.2.4.

Table 9-28 – PMD test parameter read commands transmitted by the initiator

Message length (octets)	Element name (command)	
3	01_{16}	Single read followed by: 1 octet describing the test parameter ID
~~3~~	~~02_{16}~~	~~Multiple read block followed by:~~ ~~1 octet describing the subcarrier index~~
2	03_{16}	Next multiple read
4	04_{16}	Multiple read block followed by: 2 octets describing the subcarrier index
~~4~~6	~~04_{16}~~05_{16}	Block read followed by: ~~1 octet~~2 octets describing the start subcarrier index ~~1 octet~~2 octets describing the stop subcarrier index
	All other octet values are reserved by ITU-T.	

• • •

10 Dynamic behaviour

See clause 10 of ITU-T G.992.3.

Annex A

Specific requirements for an ADSL system operating in the frequency band above POTS

(This annex forms an integral part of this Recommendation)

This annex defines those parameters of the ADSL system that have been left undefined in the main body of this Recommendation because they are unique to an ADSL service that is frequency-division duplexed with POTS.

A.1 ATU-C functional characteristics (pertains to clause 8)

A.1.1 ATU-C control parameter settings

The ATU-C control parameter settings, to be used in the parameterized parts of the main body and/or to be used in this annex are listed in Table A.1. Control Parameters are defined in clause 8.5.

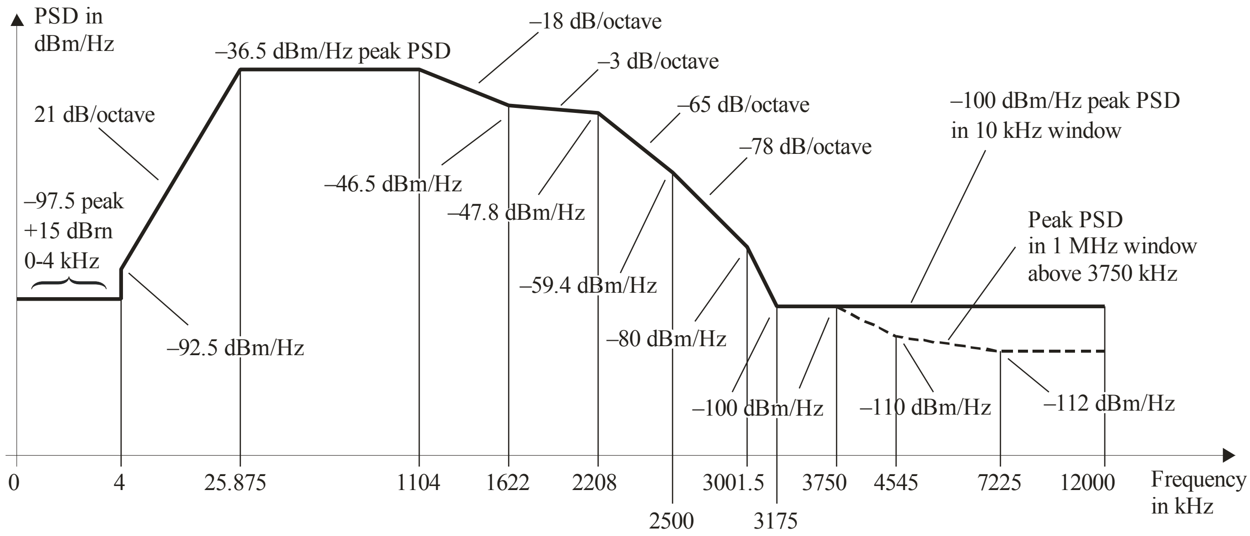
Table A.1 – ATU-C control parameter settings

Parameter	Default setting	Characteristics
NSCds	512	
NOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMATPds	20.4 dBm	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.

A.1.2 ATU-C downstream transmit spectral mask for overlapped spectrum operation (supplements clause 8.10)

The passband is defined as the band from 25.875 to 2208 kHz and is the widest possible band used (i.e., for ADSL over POTS implemented with overlapped spectrum). Limits defined within the passband apply also to any narrower bands used.

Figure A.1 defines the limit spectral mask for the transmit signal. The low-frequency stopband is defined as frequencies below 25.875 kHz and includes the POTS band, the high-frequency stopband is defined as frequencies greater than 2208 kHz.



Frequency (kHz)	PSD level (dBm/Hz)	MBW
0	–97.5	100 Hz
4	–97.5	100 Hz
4	–92.5	100 Hz
10	Interpolated	10 kHz
25.875	–36.5	10 kHz
1104	–36.5	10 kHz
1622	–46.5	10 kHz
2208	–47.8	10 kHz
2500	–59.4	10 kHz
3001.5	–80	10 kHz
3175	–100	10 kHz
12000	–100	10 kHz

Additionally, the PSD mask shall satisfy the following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	MBW
3750	–100	1 MHz
4545	–110	1 MHz
7225	–112	1 MHz
12000	–112	1 MHz

NOTE 1 – All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.
NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.
NOTE 3 – MBW specifies the measurement bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \le f_j$, where f_j is the frequency of the next specified breakpoint.
NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the [f, f + 1 MHz] window shall conform to the specification at frequency f.
NOTE 5 – The step in the PSD mask at 4 kHz is to protect ITU-T V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of –97.5 dBm/Hz at 3400 Hz. It was recognized that this might impact ITU-T V.90 performance, and so the floor was extended to 4 kHz.
NOTE 6 – All PSD and power measurements shall be made at the U-C interface.

Figure A.1 – ATU-C transmitter PSD mask for overlapped spectrum operation

A.1.2.1 Passband PSD and response

There are three different PSD masks for the ATU-C transmit signal, depending on the type of signal sent. Across the whole passband, the transmit PSD level shall not exceed the maximum passband transmit PSD level, defined as:

- *NOMPSDds* + 1 dB, for initialization signals up to and including the channel discovery phase;
- *REFPSDds* + 1 dB, during the remainder of initialization, starting with the transceiver training phase;
- *MAXNOMPSDds – PCBds* + 3.5 dB, during showtime.

The group delay variation over the passband shall not exceed 50 μs.

The maximum passband transmit PSD level allows for a 1 dB of non-ideal transmit filter effects (e.g., passband ripple and transition band rolloff).

For spectrum management purposes, the ATU-C transmitter PSD template for overlapped spectrum operation is defined in Table A.1.2-1 (informative).

Table A.1.2-1 – ATU-C transmitter PSD template for overlapped spectrum operation

Frequency (kHz)	PSD level (dBm/Hz)
0	–101
4	–101
4	–96
25.875	–40
1104	–40
1622	–50
2208	–51.3
2500	–62.9
3001.5	–83.5
3175	–100
3750	–100
4545	–110
7225	–112
12000	–112

A.1.2.2 Aggregate transmit power

There are three different PSD masks for the ATU-C transmit signal, depending on the type of signal sent (see clause A.1.2.1). In all cases:

- the aggregate transmit power in the voiceband, measured at the U-C interface, and that is delivered to the public switched telephone network (PSTN) interface, shall not exceed +15 dBrn (see [ITU-T G.996.1] for method of measurement);
- the aggregate transmit power across the whole passband shall not exceed (*MAXNOMATPds – PCBds*) by more than 0.5 dB, in order to accommodate implementational tolerances, and shall not exceed 20.9 dBm;
- the aggregate transmit power over the 0 to 12 MHz band shall not exceed (*MAXNOMATPds – PCBds*) by more than 0.9 dB, in order to account for residual transmit power in the stopbands and implementational tolerances.

The power emitted by the ATU-C is limited by the requirements in this clause. Notwithstanding these requirements, it is assumed that the ADSL will comply with applicable national requirements on emission of electromagnetic energy.

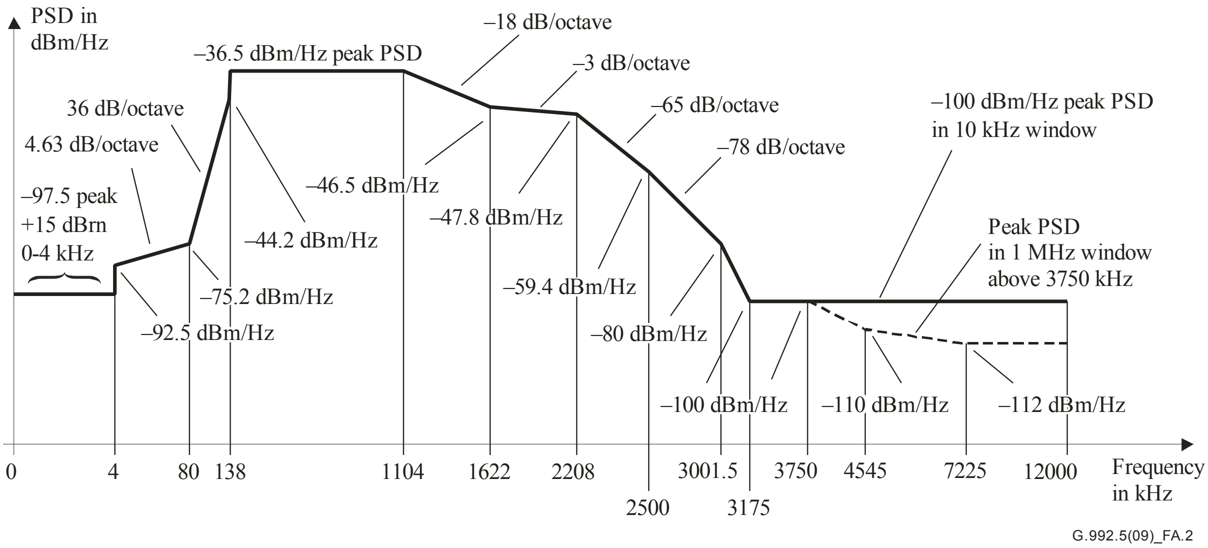
For spectrum management purposes, the PSD template nominal passband aggregate transmit power is 20.4 dBm.

A.1.3 ATU-C transmitter PSD mask for non-overlapped spectrum operation (supplements clause 8.10)

Figure A.2 defines the limit spectral mask for the ATU-C transmitted signal, which results in reduced NEXT into the ADSL upstream band, relative to the mask in clause A.1.2. Adherence to this mask will, in many cases, result in improved upstream performance of the other ADSL systems in the same or adjacent binder group, with the improvement dependent upon the other interferers. This mask differs from the mask in clause A.1.2 only in the band from 4 kHz to 138 kHz.

The passband is defined as the band from 138 to 2208 kHz. Limits defined within the passband apply also to any narrower bands used.

The low-frequency stopband is defined as frequencies below 138 kHz and includes the POTS band, the high-frequency stopband is defined as frequencies greater than 2208 kHz.



Frequency (kHz)	PSD level (dBm/Hz)	MBW
0	–97.5	100 Hz
4	–97.5	100 Hz
4	–92.5	100 Hz
10	Interpolated	10 kHz
80	–72.5	10 kHz
138	–44.2	10 kHz
138	–36.5	10 kHz
1104	–36.5	10 kHz
1622	–46.5	10 kHz
2208	–47.8	10 kHz
2500	–59.4	10 kHz
3001.5	–80	10 kHz
3175	–100	10 kHz
12000	–100	10 kHz

Additionally, the PSD mask shall satisfy the following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	MBW
3750	–100	1 MHz
4545	–110	1 MHz
7225	–112	1 MHz
12000	–112	1 MHz

NOTE 1 – All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.

NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.

NOTE 3 – MBW specifies the measurement bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the $[f, f + 1\text{ MHz}]$ window shall conform to the specification at frequency *f*.

NOTE 5 – The step in the PSD mask at 4 kHz is to protect ITU-T V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of –97.5 dBm/Hz at 3400 Hz. It was recognized that this might impact ITU-T V.90 performance, and so the floor was extended to 4 kHz.

NOTE 6 – All PSD and power measurements shall be made at the U-C interface.

Figure A.2 – ATU-C transmitter PSD mask for non-overlapped spectrum operation

A.1.3.1 Passband PSD and response

See clause A.1.2.1. For spectrum management purposes, the PSD template for non-overlapped spectrum operation is defined in Table A.1.3-1 (informative):

Table A.1.3-1 – ATU-C transmitter PSD template for non-overlapped spectrum operation

Frequency (kHz)	PSD level (dBm/Hz)
0	–101
4	–101
4	–96
80	–76
138	–47.7
138	–40
1104	–40
1622	–50
2208	–51.3
2500	–62.9
3001.5	–83.5
3175	–100
3750	–100
4545	–110
7225	–112
12000	–112

A.1.3.2 Aggregate transmit power

See clause A.1.2.2. In addition, for non-overlapped spectrum operation, the aggregate transmit power across the whole passband shall not exceed 20.4 dBm.

For spectrum management purposes, the PSD template nominal passband aggregate transmit power is 19.9 dBm.

A.2 ATU-R functional characteristics (pertains to clause 8)

A.2.1 ATU-R control parameter settings

The ATU-R control parameter settings to be used in the parameterized parts of the main body and/or to be used in this annex are listed in Table A.2. Control parameters are defined in clause 8.5.

Table A.2 – ATU-R control parameter settings

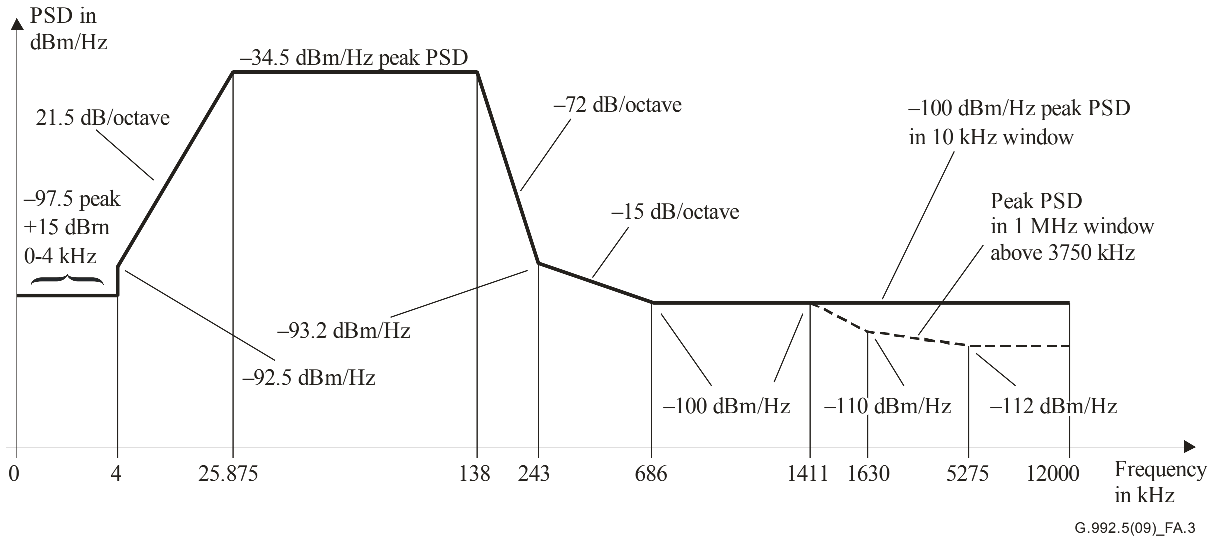
Parameter	Default setting	Characteristics
NSCus	32	
NOMPSDus	–38 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMPSDus	–38 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMATPus	12.5 dBm	Setting may be changed relative to this value during the

		ITU-T G.994.1 phase, see clause 8.13.2.

A.2.2 ATU-R upstream transmit spectral mask (supplements clause 8.10)

The passband is defined as the band from 25.875 to 138 kHz and is the widest possible band used. Limits defined within the passband also apply to any narrower bands used.

Figure A.3 defines the spectral mask for the transmit signal. The low-frequency stopband is defined as frequencies below 25.875 kHz and includes the POTS band (see also Figure A.1), the high-frequency stopband is defined as frequencies greater than 138 kHz.



Frequency (kHz)	PSD level (dBm/Hz)	MBW
0	–97.5	100 Hz
4	–97.5	100 Hz
4	–92.5	100 Hz
10	Interpolated	10 kHz
25.875	–34.5	10 kHz
138	–34.5	10 kHz
243	–93.2	10 kHz
686	–100	10 kHz
5275	–100	10 kHz
12000	–100	10 kHz

Additionally the PSD mask shall satisfy the following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	MBW
1411	–100	1 MHz
1630	–110	1 MHz
5275	–112	1 MHz
12000	–112	1 MHz

NOTE 1 – All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.

NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.

NOTE 3 – MBW specifies the measurement bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the $[f, f + 1\text{ MHz}]$ window shall conform to the specification at frequency *f*.

NOTE 5 – The step in the PSD mask at 4 kHz is to protect ITU-T V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of –97.5 dBm/Hz at 3400 Hz. It was recognized that this might impact ITU-T V.90 performance, and so the floor was extended to 4 kHz.

NOTE 6 – All PSD and power measurements shall be made at the U-R interface.

Figure A.3 – ATU-R transmitter PSD mask

A.2.2.1 Passband PSD and response

There are three different PSD masks for the ATU-R transmit signal, depending on the type of signal sent. Across the whole passband, the transmit PSD level shall not exceed the maximum passband PSD level, defined as:

- *NOMPSDus* + 1 dB, for initialization signals up to and including the channel discovery phase;

- *REFPSDus* + 1 dB, during the remainder of initialization, starting with the transceiver training phase;
- *MAXNOMPSDus* – *PCBus* + 3.5 dB, during showtime.

The group delay variation over the passband shall not exceed 50 µs.

The maximum transmit PSD level allows for a 1 dB of non-ideal transmit filter effects (e.g., passband ripple and transition band rolloff).

For spectrum management purposes, the PSD template is defined in Table A.2.2-1 (informative).

Table A.2.2-1 – ATU-R transmitter PSD template

Frequency (kHz)	PSD level (dBm/Hz)
0	–101
4	–101
4	–96
25.875	–38
138	–38
229.6	–92.9
686	–100
1411	–100
1630	–110
5275	–112
12000	–112

A.2.2.2 Aggregate transmit power

There are three different PSD masks for the ATU-R transmit signal, depending on the type of signal sent (see clause A.2.2.1). In all cases:

- the aggregate transmit power in the voiceband, measured at the U-R interface, and that which is delivered to the plain old telephone service (POTS) interface, shall not exceed +15 dBrn (see [ITU-T G.996.1] for method of measurement);
- the aggregate transmit power across the whole passband shall not exceed (*MAXNOMATPus* – *PCBus*) by more than 0.5 dB, in order to accommodate implementational tolerances, and shall not exceed 13.0 dBm;
- the aggregate transmit power over the 0 to 12 MHz band shall not exceed (*MAXNOMATPus* – *PCBus*) by more than 0.8 dB, in order to account for residual transmit power in the stopbands and implementational tolerances.

The power emitted by the ATU-R is limited by the requirements in this clause. Notwithstanding these requirements, it is assumed that the ADSL will comply with applicable national requirements on emission of electromagnetic energy.

For spectrum management purposes, the PSD template nominal passband aggregate transmit power is 12.5 dBm.

A.3 Initialization

For this annex, no additional requirements apply (relative to the main body of this Recommendation).

A.4 Electrical characteristics

This clause specifies the combination of ATU-x and high-pass filter, as shown in Figures 5-4 and 5-5; further information about the low-pass filter is specified in Annex E. The ITU-T G.992.3 requirements (except longitudinal conversion loss) applying over a frequency band up to 1104 kHz shall be met over a frequency band up to 2208 kHz.

A.4.1 Definition of impedance states

See clause A.4.1 of ITU-T G.992.3.

A.4.2 POTS current and voltage specification

See clause A.4.2 of ITU-T G.992.3.

A.4.3 Electrical characteristics for the ATU-C and for the ATU-R in the active state

See clause A.4.3 of ITU-T G.992.3.

A.4.3.1 DC characteristics

See clause A.4.3.1 of ITU-T G.992.3.

A.4.3.2 Voiceband characteristics

See clause A.4.3.2 of ITU-T G.992.3.

A.4.3.3 ADSL band characteristics

A.4.3.3.1 Longitudinal balance

See clause A.4.3.3.1 of ITU-T G.992.3, modifying the first two paragraphs with the following:

The ATU-C shall have a longitudinal conversion loss (LCL) of at least 50 dB in the frequency range from 30 kHz to 138 kHz and at least 40 dB in the frequency range from 138 kHz to 1104 kHz. The ATU-C shall have a longitudinal conversion loss (LCL) of at least 40 dB in the frequency range from 1104 kHz to 2208 kHz.

The ATU-R shall have a longitudinal conversion loss (LCL) of at least 50 dB in the frequency range from 30 kHz to 1104 kHz.The ATU-R shall have a longitudinal conversion loss (LCL) of at least 40 dB in the frequency range from 1104 kHz to 2208 kHz.

A.4.4 Electrical characteristics for the ATU-R in the high impedance state

See clause A.4.4 of ITU-T G.992.3.

Annex B

Specific requirements for an ADSL system operating in the frequency band above ISDN as defined in Appendices I and II of Recommendation ITU-T G.961

(This annex forms an integral part of this Recommendation)

This annex defines those parameters of the ADSL system that have been left undefined in the main body of this Recommendation because they are unique to an ADSL service that is frequency-division duplexed with ISDN basic access on the same digital subscriber line. The scope is to establish viable ways enabling the simultaneous deployment of ADSL and 160 kbit/s (2B + D) basic rate access with the constraint to use existing transmission technologies as those specified in Appendices I and II of [ITU-T G.961].

B.1 ATU-C functional characteristics (pertains to clause 8)

B.1.1 ATU-C control parameter settings

The ATU-C control parameter settings to be used in the parameterized parts of the main body and/or to be used in this annex are listed in Table B.1. Control parameters are defined in clause 8.5.

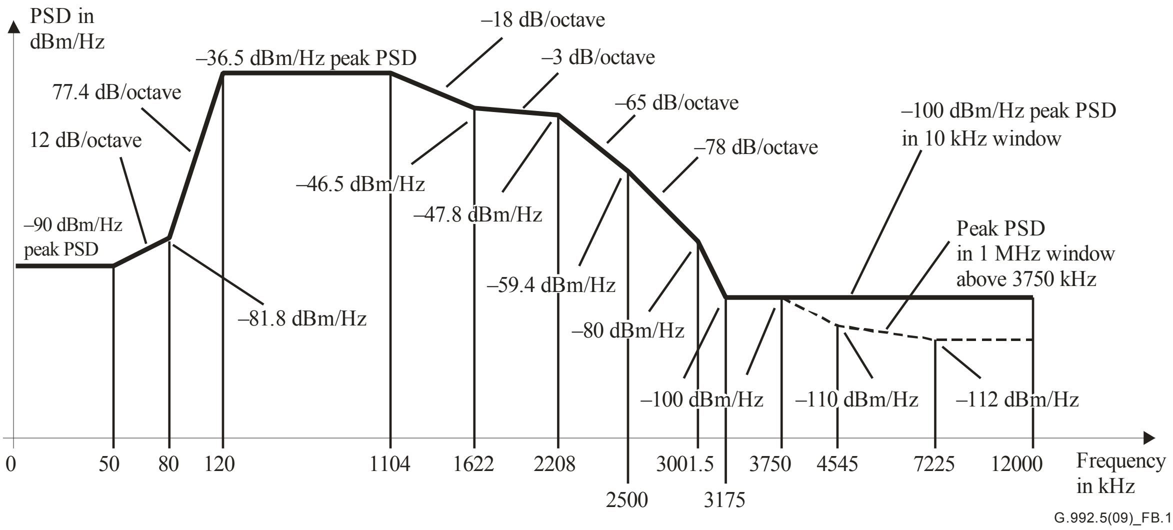
Table B.1 – ATU-C control parameter settings

Parameter	Default setting	Characteristics
NSCds	512	
NOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMATPds	19.9 dBm	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.

B.1.2 ATU-C downstream transmit spectral mask for overlapped spectrum operation (supplements clause 8.10)

The passband is defined as the band from 120 kHz (see Figure B.1) to 2208 kHz and is the widest possible band used (i.e., for ADSL over ISDN implemented with overlapped spectrum). Limits defined within the passband apply also to any narrower bands used.

Figure B.1 defines the limit spectral mask for the transmit signal. The low-frequency stopband is the ISDN band and is defined as frequencies below 120 kHz (see Figure B.1), the high-frequency stopband is defined as frequencies greater than 2208 kHz.



Frequency (kHz)	PSD level (dBm/Hz)	MBW
0	–90	10 kHz
50	–90	10 kHz
80	–81.8	10 kHz
120	–36.5	10 kHz
1104	–36.5	10 kHz
1622	–46.5	10 kHz
2208	–47.8	10 kHz
2500	–59.4	10 kHz
3001.5	–80	10 kHz
3175	–100	10 kHz
12000	–100	10 kHz

Additionally, the PSD mask shall satisfy the following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	MBW
3750	–100	1 MHz
4545	–110	1 MHz
7225	–112	1 MHz
12000	–112	1 MHz

NOTE 1 – All PSD measurements shall measure the spectral power into a resistive load having a value of 100 Ω.
NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.
NOTE 3 – MBW specifies the measurement bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.
NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the [f, f + 1 MHz] window shall conform to the specification at frequency f.
NOTE 5 – All PSD and power measurements shall be made at the U-C interface.

Figure B.1 – ATU-C transmitter PSD mask for overlapped spectrum operation

The ISDN port of the ISDN splitter shall be terminated with the appropriate 2B1Q or 4B3T design impedance for ISDN-BA as defined in [ETSI TS 102 080].

It is intended that the degradation impact on the ISDN-BA line system performance be no more than 4.5 dB and 4 dB, for 2B1Q and 4B3T line codes, respectively, at the insertion loss reference frequency.

B.1.2.1 Passband PSD and response

There are three different PSD masks for the ATU-C transmit signal, depending on the type of signal sent. Across the whole passband, the transmit PSD level shall not exceed the maximum passband transmit PSD level, defined as:

- *NOMPSDds* + 1 dB, for initialization signals up to and including the channel discovery phase;
- *REFPSDds* + 1 dB, during the remainder of initialization, starting with the transceiver training phase;
- *MAXNOMPSDds – PCBds* + 3.5 dB, during showtime.

The group delay variation over the passband shall not exceed 50 µs.

The maximum transmit PSD allows for a 1 dB of non-ideal transmit filter effects (e.g., passband ripple and transition band rolloff).

For spectrum management purposes, the PSD template is defined in Table B.1.2-1 (informative).

Table B.1.2-1 – ATU-C transmitter PSD template for overlapped spectrum operation

Frequency (kHz)	PSD level (dBm/Hz)
0	–90
50	–90
80	–85.3
120	–40
1104	–40
1622	–50
2208	–51.3
2500	–62.9
3001.5	–83.5
3175	–100
3750	–100
4545	–110
7225	–112
12000	–112

B.1.2.2 Aggregate transmit power

There are three different PSD masks for the ATU-C transmit signal, depending on the type of signal sent (see clause B.1.2.1). In all cases,

- the aggregate transmit power across the whole passband shall not exceed (*MAXNOMATPds – PCBds*) by more than 0.5 dB, in order to accommodate implementational tolerances, and shall not exceed 20.4 dBm;
- the aggregate transmit power over the 0 to 11.040 MHz band shall not exceed (*MAXNOMATPds – PCBds*) by more than 0.9 dB, in order to account for residual transmit power in the stopbands and implementational tolerances.

The power emitted by the ATU-C is limited by the requirements in this clause. Notwithstanding these requirements, it is assumed that the ADSL will comply with applicable national requirements on emission of electromagnetic energy.

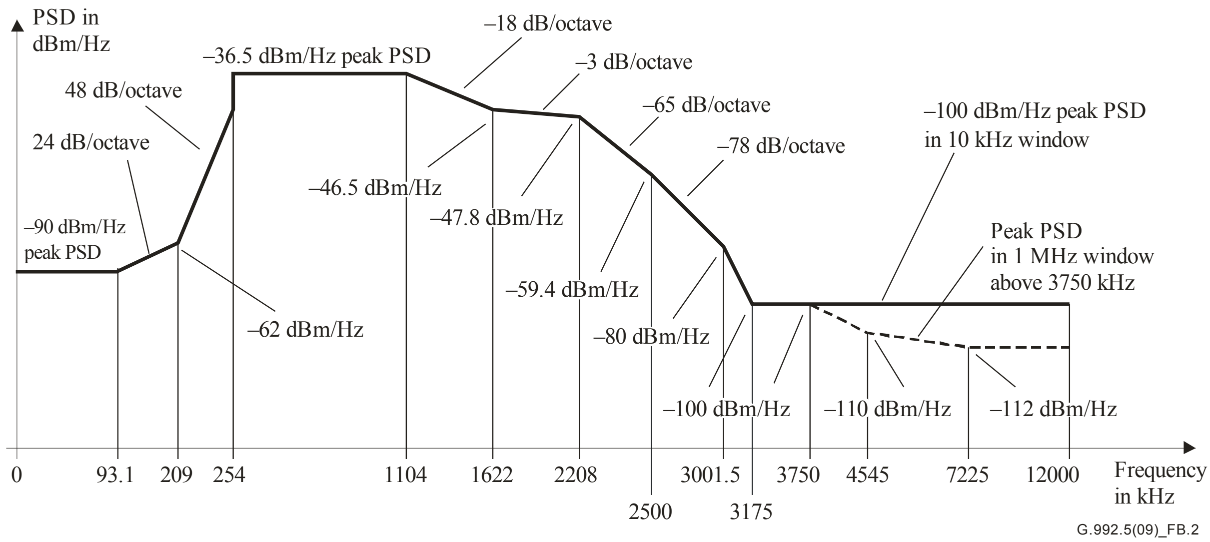
For spectrum management purposes, the PSD template nominal passband aggregate transmit power is 19.9 dBm.

B.1.3 ATU-C transmitter PSD mask for non-overlapped spectrum operation (supplements clause 8.10)

Figure B.2 defines the limit spectral mask for the ATU-C transmitted signal, which results in reduced NEXT into the ADSL upstream band, relative to the mask in clause B.1.2. Adherence to this mask will, in many cases, result in improved upstream performance of the other ADSL systems in the same or adjacent binder group, with the improvement dependent upon the other interferers. This mask differs from the mask in clause B.1.2 only in the band from 50 kHz to 254 kHz.

The passband is defined as the band from 254 to 2208 kHz. Limits defined within the passband also apply to any narrower bands used.

The low-frequency stopband is defined as frequencies below 254 kHz and includes the ISDN band; the high-frequency stopband is defined as frequencies greater than 2208 kHz.



Frequency (kHz)	PSD level (dBm/Hz)	MBW
0	–90	10 kHz
93.1	–90	10 kHz
209	–62	10 kHz
254	–48.5	10 kHz
254	–36.5	10 kHz
1104	–36.5	10 kHz
1622	–46.5	10 kHz
2208	–47.8	10 kHz
2500	–59.4	10 kHz
3001.5	–80	10 kHz
3175	–100	10 kHz
12000	–100	10 kHz

Additionally, the PSD mask shall satisfy the following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	MBW
3750	–100	1 MHz
4545	–110	1 MHz
7225	–112	1 MHz
12000	–112	1 MHz

NOTE 1 – All PSD measurements shall measure the spectral power into a resistive load having a value of 100 Ω.
NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.
NOTE 3 – MBW specifies the measurement bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.
NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the [f, f + 1 MHz] window shall conform to the specification at frequency f.
NOTE 5 – All PSD and power measurements shall be made at the U-C interface.

Figure B.2 – ATU-C transmitter PSD mask for non-overlapped spectrum operation

The ISDN port of the ISDN splitter shall be terminated with the appropriate 2B1Q or 4B3T design impedance for ISDN-BA as defined in [ETSI TS 102 080].

It is intended that the degradation impact on the ISDN-BA line system performance be no more than 4.5 dB and 4 dB, for 2B1Q and 4B3T line codes, respectively, at the insertion loss reference frequency.

B.1.3.1 Passband PSD and response

See clause B.1.2.1. For spectrum management purposes, the PSD template is defined in Table B.1.3-1 (informative).

Table B.1.3-1 – ATU-C transmitter PSD template for non-overlapped spectrum operation

Frequency (kHz)	PSD level (dBm/Hz)
0	–90
93.1	–90
209	–65.5
254	–52
254	–40
1104	–40
1622	–50
2208	–51.3
2500	–62.9
3001.5	–83.5
3175	–100
3750	–100
4545	–110
7225	–112
12000	–112

B.1.3.2 Aggregate transmit power

See clause B.1.2.2. In addition, for non-overlapped spectrum operation, the aggregate transmit power across the whole passband shall not exceed 19.8 dBm.

For spectrum management purposes, the PSD template nominal passband aggregate transmit power is 19.3 dBm.

B.2 ATU-R functional characteristics (pertains to clause 8)

B.2.1 ATU-R control parameter settings

The ATU-R control parameter settings to be used in the parameterized parts of the main body and/or to be used in this annex are listed in Table B.2. Control parameters are defined in clause 8.5.

Table B.2 – ATU-R control parameter settings

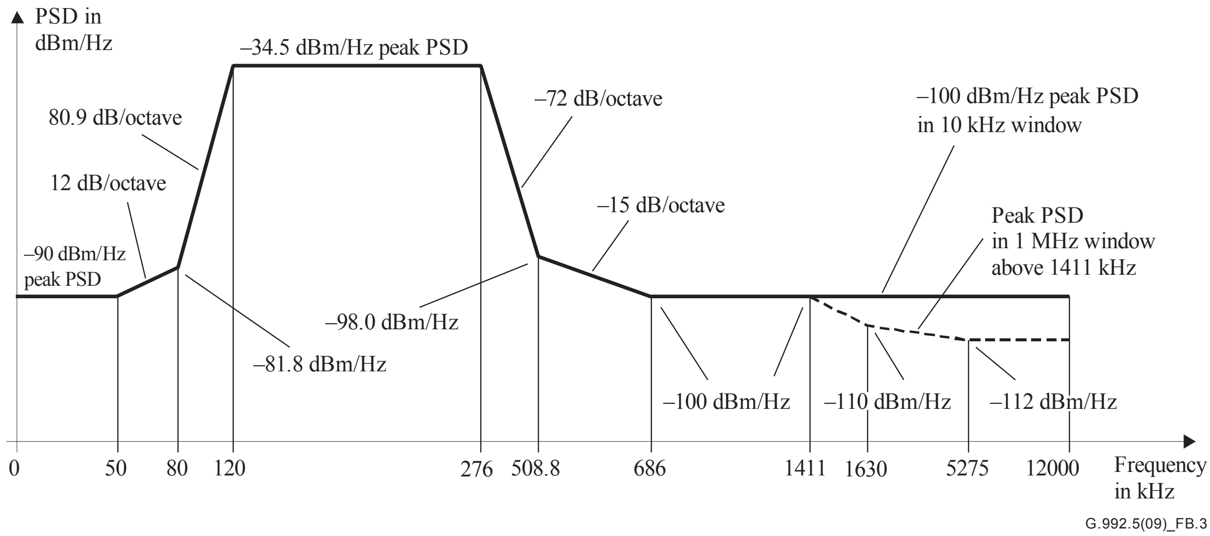
Parameter	Default setting	Characteristics
NSCus	64	
NOMPSDus	–38 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMPSDus	–38 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMATPus	13.3 dBm	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.

Tones 1 to 32	Enabled/disabled	Signifies that the transmission of upstream tones 1 to 32 (or a subset thereof) is enabled/disabled. Negotiated in the ITU-T G.994.1 phase (see clause B.3).

B.2.2 ATU-R upstream transmit spectral mask (supplements clause 8.10)

The passband is defined as the band from 120 kHz (see Figure B.3) to 276 kHz and is the widest possible band used. Limits defined within the passband also apply to any narrower bands used.

Figure B.3 defines the spectral mask for the transmit signal. The low-frequency stopband is the ISDN band and is defined as frequencies below 120 kHz (see Figure B.3), the high-frequency stopband is defined as frequencies greater than 276 kHz.



Frequency (kHz)	PSD level (dBm/Hz)	MBW
0	–90	10 kHz
50	–90	10 kHz
80	–81.8	10 kHz
120	–34.5	10 kHz
276	–34.5	10 kHz
508.8	–98.0	10 kHz
686	–100	10 kHz
5275	–100	10 kHz
12000	–100	10 kHz

Additionally the PSD mask shall satisfy the following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	MBW
1411	–100	1 MHz
1630	–110	1 MHz
5275	–112	1 MHz
12000	–112	1 MHz

NOTE 1 – All PSD measurements shall measure the spectral power into a resistive load having a value of 100 Ω.

NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.

NOTE 3 – MBW specifies the measurement bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the [*f*, *f* + 1 MHz] window shall conform to the specification at frequency *f*.

NOTE 5 – All PSD and power measurements shall be made at the U-R interface.

NOTE 6 – The upstream PSD mask is intended for use with ISDN 2B1Q and ISDN 4B3T. However, some deployments have reported field issues with ISDN 4B3T NT activation when operating with ADSL overlay. ISDN passband versus ADSL passband tradeoff and ISDN splitter characteristics need further study. A result thereof could be a limitation of the ADSL transmit power below 138 kHz when operating over ISDN 4B3T. Such transmit power limitation can be achieved through frequency domain shaping or masking of the tones below tone index 33 (if the ATU-R transmitter supports tones 1 to 32) or through time-domain filtering with filter rolloff from 138 kHz (if the ATU-R transmitter does not support tones 1 to 32).

Figure B.3 – ATU-R transmitter PSD mask

The ISDN port of the ISDN splitter shall be terminated with the appropriate 2B1Q or 4B3T design impedance for ISDN-BA as defined in [ETSI TS 102 080].

It is intended that the degradation impact on the ISDN-BA line system performance be no more than 4.5 dB and 4 dB, for 2B1Q and 4B3T line codes, respectively, at the insertion loss reference frequency.

B.2.2.1 Passband PSD and response

There are three different PSD masks for the ATU-R transmit signal, depending on the type of signal sent. Across the whole passband, the transmit PSD level shall not exceed the maximum passband transmit PSD level, defined as:

- *NOMPSDus* + 1 dB, for initialization signals up to and including the channel discovery phase;
- *REFPSDus* + 1 dB, during the remainder of initialization, starting with the transceiver training phase;
- *MAXNOMPSDus* – *PCBus* + 3.5 dB, during showtime.

The group delay variation over the passband shall not exceed 50 μs.

The maximum transmit PSD allows for a 1 dB of non-ideal transmit filter effects (e.g., passband ripple and transition band rolloff).

For spectrum management purposes, the PSD template is defined in Table B.2.2-1 (informative).

Table B.2.2-1 – ATU-R transmitter PSD template

Frequency (kHz)	PSD level (dBm/Hz)
0	–90
50	–90
80	–85.3
120	–38
276	–38
491	–97.8
686	–100
1411	–100
1630	–110
5275	–112
12000	–112

B.2.2.2 Aggregate transmit power

See clause B.2.2.2 of ITU-T G.992.3.

B.2.3 Data subcarriers (replaces clause 8.8.1.1)

See clause B.2.3 of ITU-T G.992.3.

B.2.4 Modulation by the inverse discrete Fourier transform (supplements clause 8.8.2)

See clause B.2.4 of ITU-T G.992.3.

B.3 Initialization

See clause B.3 of ITU-T G.992.3.

B.4 Electrical characteristics

This clause specifies the combination of ATU-x and high-pass filter, as shown in Figures 5-4 and 5-5; further information about the low-pass filter is specified in Annex E.

All electrical characteristics shall be met in the presence of all of the ISDN signals, as defined in Appendices I and II of [ITU-T G.961] (as applicable to the ISDN service).

The ITU-T G.992.3 requirements (except longitudinal conversion loss) applying over a frequency band up to 1104 kHz shall be met over a frequency band up to 2208 kHz.

B.4.1 Electrical characteristics for the ATU-C and for the ATU-R in the active state

B.4.1.1 DC characteristics

See clause B.4.1.1 of ITU-T G.992.3.

B.4.1.2 ISDN band characteristics

See clause B.4.1.2 of ITU-T G.992.3.

B.4.1.3 ADSL band characteristics

B.4.1.3.1 Longitudinal balance

The ATU-C shall have a longitudinal conversion loss (LCL) of at least 50 dB in the frequency range from 120 kHz to 276 kHz and at least 40 dB in the frequency range from 276 kHz to 1104 kHz.

The ATU-R shall have a longitudinal conversion loss (LCL) of at least 50 dB in the frequency range from 120 kHz to 1104 kHz.

The longitudinal conversion loss (LCL) requirements in the frequency range from 1104 kHz to 2208 kHz are defined in clause A.4.

The method of measurement shall be identical to the method defined for ADSL over POTS in clause A.4.3.3.1.

Annex C

Specific requirements for an ADSL system operating in the same cable as ISDN as defined in Appendix III of Recommendation ITU-T G.961

(This annex forms an integral part of this Recommendation)

Annex C to this Recommendation has been published independently due to its size and its specific structure.

Annex D

ATU-C and ATU-R state diagrams

(This annex forms an integral part of this Recommendation)

See Annex D of ITU-T G.992.3.

Annex E

POTS and ISDN basic access splitters

(This annex forms an integral part of this Recommendation)

See Annex E of ITU-T G.992.3.

For operation according to Annexes A, B and I, the ITU-T G.992.3 requirements applying over a frequency band up to 1104 kHz shall be met over a frequency band up to 2208 kHz.

Annex F

ATU-x performance requirements for region A (North America)

(This annex forms an integral part of this Recommendation)

F.1 Performance requirements for operation of ADSL over POTS (Annex A)

For further study.

F.2 Performance requirements for operation of all-digital mode ADSL (Annex I)

For further study.

Annex G

ATU-x performance requirements for region B (Europe)

(This annex forms an integral part of this Recommendation)

G.1 Performance requirements for operation of ADSL over POTS (Annex A)

For further study.

G.2 Performance requirements for operation of ADSL over ISDN (Annex B)

For further study.

G.3 Performance requirements for operation of all-digital mode ADSL (Annex I)

For further study.

G.4 Performance requirements for operation of all-digital mode ADSL (Annex J)

For further study.

Annex H

Specific requirements for a synchronized symmetrical DSL (SSDSL) system operating in the same cable binder as ISDN as defined in Appendix III of Recommendation ITU-T G.961

For further study.

Annex I

All-digital mode ADSL with improved spectral compatibility with ADSL over POTS

(This annex forms an integral part of this Recommendation)

This annex defines those parameters of the ADSL system that have been left undefined in the main body of this Recommendation because they are unique to an all-digital ADSL service with improved spectral compatibility with ADSL over POTS.

I.1 ATU-C functional characteristics (pertains to clause 8)

I.1.1 ATU-C control parameter settings

The ATU-C control parameter settings, to be used in the parameterized parts of the main body of this Recommendation and/or to be used in this annex are listed in Table I.1. Control parameters are defined in clause 8.5.

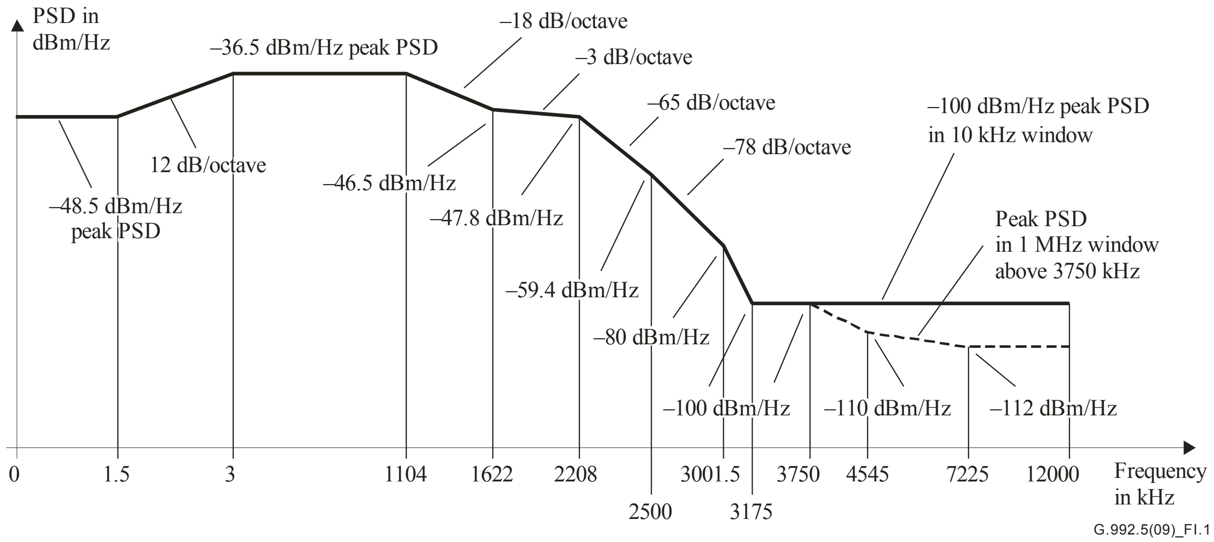
Table I.1 – ATU-C control parameter settings

Parameter	Default setting	Characteristics
NSCds	512	
NOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMATPds (operation per clause I.1.2)	20.4 dBm	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.

I.1.2 ATU-C downstream transmit spectral mask for overlapped spectrum operation (supplements clause 8.10)

The passband is defined as the band from 3 to 2208 kHz and is the widest possible band used (i.e., implemented with overlapped spectrum). Limits defined within the passband apply also to any narrower bands used.

Figure I.1 defines the limit spectral mask for the transmit signal. The low-frequency stopband is defined as frequencies below 3 kHz, the high-frequency stopband is defined as frequencies greater than 2208 kHz.



Frequency (kHz)	PSD level (dBm/Hz)	MBW
0	–48.5	100 Hz
1.5	–48.5	100 Hz
3	–36.5	100 Hz
10	–36.5	10 kHz
25.875	–36.5	10 kHz
1104	–36.5	10 kHz
1622	–46.5	10 kHz
2208	–47.8	10 kHz
2500	–59.4	10 kHz
3001.5	–80	10 kHz
3175	–100	10 kHz
12000	–100	10 kHz

Additionally, the PSD mask shall satisfy the following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	MBW
3750	–100	1 MHz
4545	–110	1 MHz
7225	–112	1 MHz
12000	–112	1 MHz

NOTE 1 – All PSD measurements are in 100 Ω.

NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.

NOTE 3 – MBW specifies the measurement bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the [*f*, *f* + 1 MHz] window shall conform to the specification at frequency *f*.

NOTE 5 – All PSD and power measurements shall be made at the U-C interface.

NOTE 6 – When deployed in the same cable as ADSL-over-POTS (Annex A of [b-ITU-T G.992.1], Annexes A and B of [b-ITU-T G.992.2], Annex A of [ITU-T G.992.3] and Annex A of [b-ITU-T G.992.4]), there may be a spectral compatibility issue between the two systems due to the overlap of the all-digital loop downstream channel with the ADSL-over-POTS upstream channel at frequencies below 138 kHz. Detailed study of spectrum compatibility is referred to regional bodies. Deployment restrictions for systems using the downstream PSD masks defined in this annex may be imposed (e.g., by the regional regulatory authority).

Figure I.1 – All-digital mode ATU-C transmitter PSD mask for overlapped spectrum operation

I.1.2.1 Passband PSD and response

There are three different PSD masks for the ATU-C transmit signal, depending on the type of signal sent. Across the whole passband, the transmit PSD level shall not exceed the maximum passband transmit PSD level, defined as:

- *NOMPSDds* + 1 dB, for initialization signals up to and including the channel discovery phase;
- *REFPSDds* + 1 dB, during the remainder of initialization, starting with the transceiver training phase;
- *MAXNOMPSDds* – *PCBds* + 3.5 dB, during showtime.

The group delay variation over the passband shall not exceed 50 µs.

The maximum passband transmit PSD level allows for a 1 dB of non-ideal transmit filter effects (e.g., passband ripple and transition band rolloff).

For spectrum management purposes, the ATU-C transmitter PSD template for overlapped spectrum operation is defined in Table I.1.2-1 (informative).

Table I.1.2-1 – ATU-C transmitter PSD template for overlapped spectrum operation

Frequency (kHz)	PSD level (dBm/Hz)
0	–52
1.5	–52
3	–40
1104	–40
1622	–50
2208	–51.3
2500	–62.9
3001.5	–83.5
3175	–100
3750	–100
4545	–110
7225	–112
12000	–112

I.1.2.2 Aggregate transmit power

There are three different PSD masks for the ATU-C transmit signal, depending on the type of signal sent (see clause I.1.2.1). In all cases:

- the aggregate transmit power across the whole passband shall not exceed (*MAXNOMATPds* – *PCBds*) by more than 0.5 dB, in order to accommodate implementational tolerances, and shall not exceed 20.9 dBm;
- the aggregate transmit power over the 0 to 12 MHz band shall not exceed (*MAXNOMATPds* – *PCBds*) by more than 0.9 dB, in order to account for residual transmit power in the stopbands and implementational tolerances.

The power emitted by the ATU-C is limited by the requirements in this clause. Notwithstanding these requirements, it is assumed that the ADSL will comply with applicable national requirements on emission of electromagnetic energy.

For spectrum management purposes, the PSD template nominal passband aggregate transmit power is 20.4 dBm.

I.1.3 ATU-C transmitter PSD mask for non-overlapped spectrum operation (supplements clause 8.10)

The ATU-C transmit spectral mask shall be identical to the ATU-C transmit spectral mask for non-overlapped spectrum operation over POTS, as defined in Figure A.2, with the following modification:

> For $0 < f < 4$, the PSD shall be below –97.5 dBm/Hz (no extra limitation of max power in 0-4 kHz band).

Adherence to this mask will, in many cases, result in improved upstream performance of the other ADSL systems in the same or adjacent binder group, with the improvement dependent upon the other interferers. This mask differs from the mask in clause I.1.2 only in the band below 138 kHz.

The passband is defined as the band from 138 to 2208 kHz. Limits defined within the passband also apply to any narrower bands used.

The low-frequency stopband is defined as frequencies below 138 kHz, the high-frequency stopband is defined as frequencies greater than 2208 kHz.

I.1.3.1 Passband PSD and response

See clause A.1.3.1.

I.1.3.2 Aggregate transmit power

See clause A.1.3.2.

I.2 ATU-R functional characteristics (pertains to clause 8)

I.2.1 ATU-R control parameter settings

The ATU-R control parameter settings to be used in the parameterized parts of the main body and/or to be used in this annex are listed in Table I.2. Control Parameters are defined in clause 8.5.

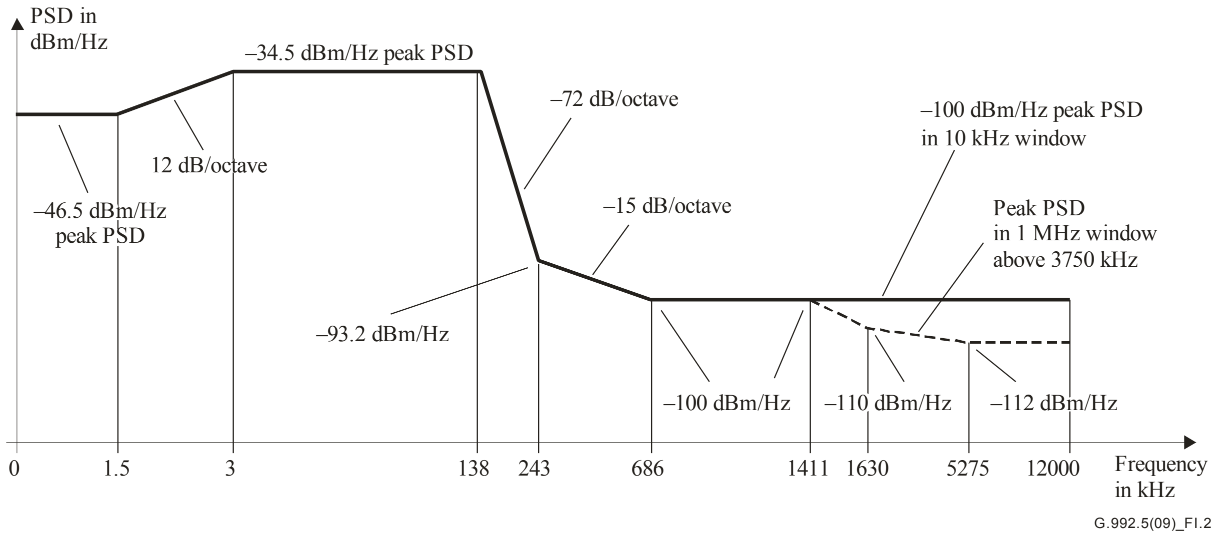
Table I.2 – ATU-R control parameter settings

Parameter	Default setting	Characteristics
NSCus	32	
NOMPSDus	–38 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMPSDus	–38 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMATPus	13.3 dBm	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.

I.2.2 ATU-R upstream transmit spectral mask (supplements clause 8.10)

The passband is defined as the band from 3 to 138 kHz and is the widest possible band used. Limits defined within the passband apply also to any narrower bands used.

Figure I.2 defines the spectral mask for the transmit signal. The low-frequency stopband is defined as frequencies below 3 kHz, the high-frequency stopband is defined as frequencies greater than 138 kHz.



Frequency (kHz)	PSD level (dBm/Hz)	MBW
0	–46.5	100 Hz
1.5	–46.5	100 Hz
3	–34.5	100 Hz
10	–34.5	10 kHz
138	–34.5	10 kHz
243	–93.2	10 kHz
686	–100	10 kHz
5275	–100	10 kHz
12000	–100	10 kHz

Additionally, the PSD mask shall satisfy the following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	MBW
1411	–100	1 MHz
1630	–110	1 MHz
5275	–112	1 MHz
12000	–112	1 MHz

NOTE 1 – All PSD measurements are in 100 Ω.

NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.

NOTE 3 – MBW specifies the measurement bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the [*f*, *f* + 1 MHz] window shall conform to the specification at frequency *f*.

NOTE 5 – All PSD and power measurements shall be made at the U-R interface.

Figure I.2 – All-digital mode ATU-R transmitter PSD mask

I.2.2.1 Passband PSD and response

There are three different PSD masks for the ATU-C transmit signal, depending on the type of signal sent. Across the whole passband, the transmit PSD level shall not exceed the maximum passband PSD level, defined as:

- *NOMPSDus* + 1 dB, for initialization signals up to and including the channel discovery phase;
- *REFPSDus* + 1 dB, during the remainder of initialization, starting with the transceiver training phase;
- *MAXNOMPSDus* – *PCBus* + 3.5 dB, during showtime.

The group delay variation over the passband shall not exceed 50 µs.

The maximum transmit PSD level allows for a 1 dB of non-ideal transmit filter effects (e.g., passband ripple and transition band rolloff).

For spectrum management purposes, the PSD template is defined in Table I.2.2-1 (informative).

Table I.2.2-1 – ATU-R transmitter PSD template

Frequency (kHz)	PSD level (dBm/Hz)
0	–50
1.5	–50
3	–38
138	–38
229.6	–92.9
686	–100
1411	–100
1630	–110
5275	–112
12000	–112

I.2.2.2 Aggregate transmit power

There are three different PSD masks for the ATU-R transmit signal, depending on the type of signal sent (see clause I.2.2.1). In all cases:

- the aggregate transmit power across the whole passband shall not exceed (*MAXNOMATPus – PCBus*) by more than 0.5 dB, in order to accommodate implementational tolerances, and shall not exceed 13.8 dBm;
- the aggregate transmit power over the 0 to 12 MHz band shall not exceed (*MAXNOMATPus – PCBus*) by more than 0.8 dB, in order to account for residual transmit power in the stopbands and implementational tolerances.

The power emitted by the ATU-R is limited by the requirements in this clause. Notwithstanding these requirements, it is assumed that the ADSL will comply with applicable national requirements on emission of electromagnetic energy.

For spectrum management purposes, the PSD template nominal passband aggregate transmit power is 13.3 dBm.

I.3 Initialization

For this annex, no additional requirements apply (relative to the main body of this Recommendation).

I.4 Electrical characteristics

I.4.1 Wetting current (Region A – North America)

See clause I.4.1 of ITU-T G.992.3, adding the following text at the end of this clause:

The ITU-T G.992.3 requirements (except longitudinal conversion loss) applying over a frequency band up to 1104 kHz shall be met over a frequency band up to 2208 kHz.

• • •

I.4.2 Wetting current (Region B – Europe)

See clause I.4.2 of ITU-T G.992.3.

I.4.3 ADSL band characteristics

I.4.3.1 Longitudinal balance

The ATU-C shall have a longitudinal conversion loss (LCL) of at least 50 dB in the frequency range from 4 kHz to 138 kHz and at least 40 dB in the frequency range from 138 kHz to 1104 kHz.

The ATU-R shall have a longitudinal conversion loss (LCL) of at least 50 dB in the frequency range from 4 kHz to 1104 kHz.

The longitudinal conversion loss (LCL) requirements in the frequency range from 1104 kHz to 2208 kHz are defined in clause A.4.

Test set-up and methodology is defined in clause A.4. The measurement of the longitudinal balance in the specified band shall be performed as shown in Figure A.4. The balance shall be measured in the absence of a DC bias voltage, with the modem under test active (i.e., powered with transmitter and receiver active and initializing or in showtime).

Annex J

All-digital mode ADSL with improved spectral compatibility with ADSL over ISDN

(This annex forms an integral part of this Recommendation)

J.1 ATU-C functional characteristics (pertains to clause 8)

J.1.1 ATU-C control parameter settings

The ATU-C control parameter settings, to be used in the parameterized parts of the main body and/or to be used in this annex are listed in Table J.1. Control parameters are defined in clause 8.5.

Table J.1 – ATU-C control parameter settings

Parameter	Default setting	Characteristics
NSCds	512	
NOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMATPds (operation per clause J.1.2)	20.4 dBm	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.

J.1.2 ATU-C downstream transmit spectral mask for overlapped spectrum operation (supplements clause 8.10)

The ATU-C transmit spectral mask shall be identical to the ATU-C transmit spectral mask for overlapped spectrum operation, as defined in Figure I.1.

The passband is defined as the band from 3 to 2208 kHz and is the widest possible band used (i.e., implemented with overlapped spectrum). Limits defined within the passband apply also to any narrower bands used.

The low-frequency stopband is defined as frequencies below 3 kHz, the high-frequency stopband is defined as frequencies greater than 2208 kHz.

NOTE – When deployed in the same cable as ADSL-over-POTS (see Annex A of [b-ITU-T G.992.1], Annexes A and B of [b-ITU-T G.992.2], Annex A of [ITU-T G.992.1] and Annex A of [ITU-T-G.992.4]) there may be a spectral compatibility issue between the two systems due to the overlap of the all-digital loop downstream channel with the ADSL-over-POTS upstream channel at frequencies below 138 kHz. Detailed study of spectrum compatibility is referred to regional bodies. Deployment restrictions for systems using the downstream PSD masks defined in this annex may be imposed (e.g., by the regional regulatory authority).

J.1.2.1 Passband PSD and response

See clause I.1.2.1.

J.1.2.2 Aggregate transmit power

See clause I.1.2.2.

J.1.3 ATU-C downstream transmit spectral mask for non-overlapped spectrum operation (supplements clause 8.10)

The ATU-C transmit spectral mask shall be identical to the ATU-C transmit spectral mask for non-overlapped spectrum operation over ISDN, as defined in Figure B.2.

Adherence to this mask will, in many cases, result in improved upstream performance of the other ADSL systems in the same or adjacent binder group, with the improvement dependent upon the other interferers. This mask differs from the mask in clause J.1.2 only in the band below 254 kHz.

The passband is defined as the band from 254 to 2208 kHz. Limits defined within the passband also apply to any narrower bands used.

The low-frequency stopband is defined as frequencies below 254 kHz, the high-frequency stopband is defined as frequencies greater than 2208 kHz.

J.1.3.1 Passband PSD and response

See clause B.1.3.1.

J.1.3.2 Aggregate transmit power

See clause B.1.3.2.

J.2 ATU-R functional characteristics (pertains to clause 8)

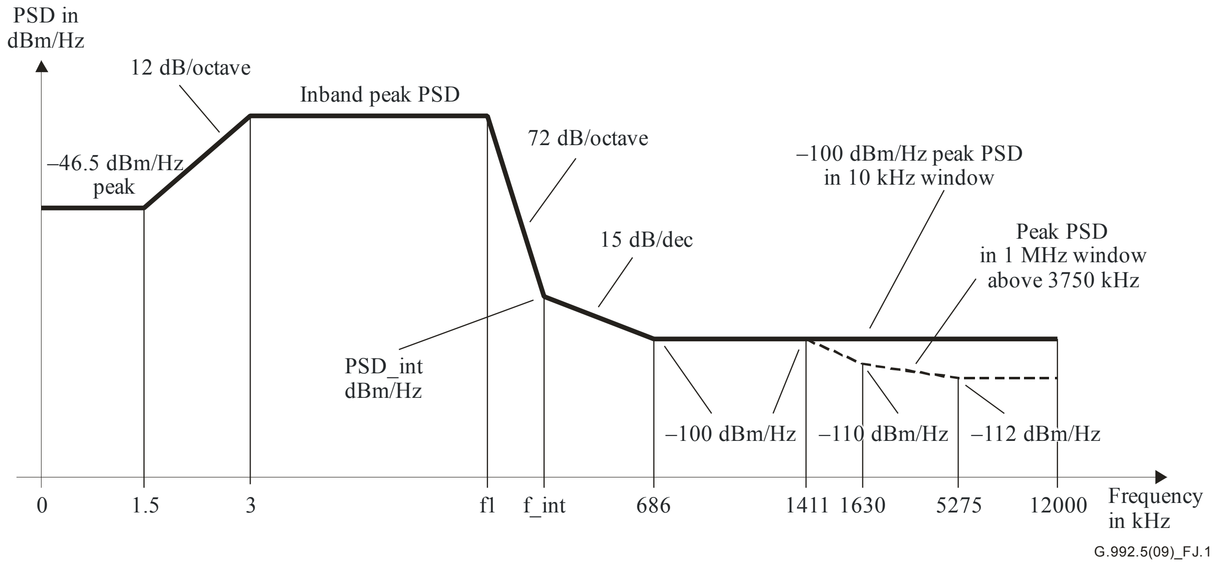
J.2.1 ATU-R control parameter settings

See clause J.2.1 of ITU-T G.992.3.

J.2.2 ATU-R upstream transmit spectral mask (supplements clause 8.10)

See clause J.2.2 of ITU-T G.992.3, modifying Note 2, Figure J.1 and Table J.3 as follows:

NOTE 2 – When deployed in the same cable as ADSL-over-POTS (see Annex A of [b-ITU-T G.992.1], Annexes A and B of [b-ITU-T G.992.2], Annex A of ~~this Recommendation~~[ITU-T G.992.3], Annex A of [b-ITU-T G.992.4] and Annex A of [b-ITU-T G.992.5]), there may be a spectral compatibility issue between the two systems due to the overlap of the all-digital mode upstream channel with the ADSL-over-POTS downstream channel at frequencies above 138 kHz. Detailed study of spectrum compatibility is referred to regional bodies. Deployment restrictions for systems using the upstream PSD masks defined in this annex may be imposed (e.g., by the regional regulatory authority).



Frequency (kHz)	PSD level (dBm/Hz)	Measurement ~~BW~~MBW
0	–46.5	100 Hz
1.5	–46.5	100 Hz
3	*Inband_peak_PSD*	100 Hz
10	*Inband_peak_PSD*	10 kHz
*f*1	*Inband_peak_PSD*	10 kHz
f_int	*PSD_int*	10 kHz
686	–100	10 kHz
5275	–100	10 kHz
12 000	–100	10 kHz

Additionally, the PSD mask shall satisfy the following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	Measurement ~~BW~~MBW
1 411	–100	1 MHz
1 630	–110	1 MHz
5 275	–112	1 MHz
12 000	–112	1 MHz

NOTE 1 – All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.

NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(f) plot.

NOTE 3 – MBW specifies the measurement bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the [f, f+1 MHz] window shall conform to the specification at frequency f.

NOTE 5 – All PSD and power measurements shall be made at the U-R interface.

Figure J.1 – ~~The family of~~ ATU-R transmitter PSD mask~~s~~

Table J.3 – Inband peak PSD, PSD_int and the frequencies *f*1 and ~~*f*2~~f_int

Upstream mask number	Designator	Template nominal PSD (dBm/Hz)	Template maximum aggregate transmit power (dBm)	Inband peak PSD (dBm/Hz)	Frequency *f*1 (kHz)	Intercept frequency *f_int* (kHz)	Intercept PSD level *PSD_int* (dBm/Hz)
1	ADLU-32	–38.0	13.4	–34.5	138.00	242.92	–93.2
2	ADLU-36	–38.5	13.4	–35.0	155.25	274.00	–94.0
3	ADLU-40	–39.0	13.4	–35.5	172.50	305.16	–94.7
4	ADLU-44	–39.4	13.4	–35.9	189.75	336.40	–95.4
5	ADLU-48	–39.8	13.4	–36.3	207.00	367.69	–95.9
6	ADLU-52	–40.1	13.4	–36.6	224.25	399.04	–96.5
7	ADLU-56	–40.4	13.4	–36.9	241.50	430.45	–97.0
8	ADLU-60	–40.7	13.4	–37.2	258.75	461.90	–97.4
9	ADLU-64	–41.0	13.4	–37.5	276.00	493.41	–97.9

J.2.2.1 Passband PSD and response

See clause J.2.2.1 of ITU-T G.992.3.

J.2.2.2 Aggregate transmit power

See clause J.2.2.2 of ITU-T G.992.3.

J.3 Initialization

The ATU-C and ATU-R shall support all upstream PSD masks listed in Table J.3.

J.3.1 Handshake – ATU-C (supplements clause 8.13.2.1)

Replace clause J.3.1 of ITU-T G.992.3 with the following:

The ITU-T G.994.1 codepoints required for the initialization of ATU-C and ATU-R shall be contained in an "Annex J submode PSD masks" SPAR(2) parameter block. This parameter block shall be added to the ITU-T G.994.1 codetree defined for this annex (all-digital mode ADSL with improved spectral compatibility with ADSL over ISDN).

J.3.1.1 CL messages (supplements clause 8.13.2.1.1)

See clause J.3.1.1 of ITU-T G.992.3.

J.3.1.2 MS messages (supplements clause 8.13.2.1.2)

See clause J.3.1.2 of ITU-T G.992.3.

J.3.2 Handshake – ATU-R (supplements clause 8.13.2.2)

Replace clause J.3.2 of ITU-T G.992.3 with the following:

The ITU-T G.994.1 codepoints required for the initialization of ATU-C and ATU-R shall be contained in an "Annex J submode PSD masks" SPAR(2) parameter block. This parameter block shall be added to the ITU-T G.994.1 codetree defined for this annex (all-digital mode ADSL with improved spectral compatibility with ADSL over ISDN).

J.3.2.1 CLR messages (supplements clause 8.13.2.2.1)

See clause J.3.2.1 of ITU-T G.992.3.

J.3.2.2 MS messages (supplements clause 8.13.2.2.2)

See clause J.3.2.2 of ITU-T G.992.3.

J.3.3 Spectral bounds and shaping parameters (supplements clause 8.13.2.4)

See clause M.3.3.

J.3.4 Upstream PSD shaping

See clause J.3.4 of ITU-T G.992.3, adding the following text at the beginning of this clause:

The upstream spectrum shaping for this annex is defined in the same way as for Annex J of [ITU-T G.992.3]. The difference with clause J.3.4 of [ITU-T G.992.3] is the handshake codepoints being identically defined but added under the Spar(1) codetree relating to this annex.

J.4 Electrical characteristics

The ATU shall meet the electrical characteristics defined in clause I.4. The ITU-T G.992.3 requirements (except longitudinal conversion loss) applying over a frequency band up to 1104 kHz shall be met over a frequency band up to 2208 kHz.

The ATU-C longitudinal conversion loss (LCL) requirements shall apply over the frequency ranges from 4 kHz to 276 kHz and from 276 kHz to 1104 kHz, respectively. The longitudinal conversion loss (LCL) requirements in the frequency range from 1104 kHz to 2208 kHz are defined in clause A.4.

Annex K

TPS-TC functional descriptions

(This annex forms an integral part of this Recommendation)

See Annex K of ITU-T G.992.3, with the following changes:

1) *The G.994.1 codepoints shall represent the data rate divided by 8000 bit/s.*

2) *The ATU shall support a net data rate of at least 16 Mbit/s.* net_min_n, net_max_n *and* $net\_reserve_n$.

3) *The number of subcarriers is 511. For Table K.3c, all valid R, S, D and* N_{FEC} *values listed in Table 7-8 are allowed, within the mandatory (*N_{FEC0} *– 1) × (*D_0 *– 1) values. For Table K.3d, in addition, the optional (*N_{FEC0} *– 1) × (*D_0 *– 1) values are allowed.*

Table K.3a – *INP_min* and *delay_max*-related downstream net data rates limits (in kbit/s)

		INP_min						
		0	**½**	**1**	**2**	**4**	**8**	**16**
delay_max [ms]	**1 (Note)**	24432	0	0	0	0	0	0
	2	24432	7104	3008	960	0	0	0
	4	24432	15232	7104	3008	960	0	0
	8	24432	22896	15232	7104	3008	960	0
	16	24432	22896	15232	7552	3520	1472	448
	32	24432	22896	15232	7552	3712	1728	704
	63	24432	22896	15232	7552	3712	1728	704
NOTE – In [ITU-T G.997.1], a 1 ms delay is reserved to mean that $S_p \leq 1$ and $D_p = 1$.								

• • •

Table K.3c – *INP_min* and *delay_max*-related downstream net data rates limits using the optional D_0 values for downstream latency path #0 (in kbit/s)

		INP_min						
		0	**½**	**1**	**2**	**4**	**8**	**16**
delay_max [ms]	**1 (Note)**	29556	0	0	0	0	0	0
	2	29556	25718	20928	7616	0	0	0
	4	29556	27613	25718	21093	7616	0	0
	8	29556	27809	26042	22244	14455	8112	0
	16	29556	27809	26042	22244	14455	8112	4024
	32	29556	27809	26042	22244	14455	8112	4024
	63	29556	27809	26042	22244	14455	8112	4024

NOTE 1 – In [ITU-T G.997.1], a 1 ms delay is reserved to mean that $S_p \leq 1$ and $D_p = 1$.
NOTE 2 – For this table, all valid R, S, D and N_{FEC} values listed in Table 7-8 are allowed, within the mandatory $(N_{FEC0} - 1) \times (D_0 - 1)$ values.

Table K.3d – INP_min and delay_max-related downstream net data rates limits using the optional D_0 values and optional $(N_{FEC0} - 1) \times (D_0 - 1)$ values for downstream latency path #0 (in kbit/s)

		INP_min						
		0	**½**	**1**	**2**	**4**	**8**	**16**
delay_max (ms)	**1** (Note)	29556	0	0	0	0	0	0
	2	29556	25718	20928	7616	0	0	0
	4	29556	27612	25718	21092	7616	0	0
	8	29556	28394	27217	24703	19092	8112	0
	16	29556	28394	27217	24703	19092	10844	4024
	32	29556	28394	27217	24703	19092	10844	5393
	63	29556	28394	27217	24703	19092	10844	5393

NOTE 1 – In [ITU-T G.997.1], a 1 ms delay is reserved to mean that $S_p \leq 1$ and $D_p = 1$.
NOTE 2 – For this table, in addition, the optional $(N_{FEC0} - 1) \times (D_0 - 1)$ values are allowed.

Annex L

This annex is intentionally left blank

Annex M

Specific requirements for an ADSL system with extended upstream bandwidth, operating in the frequency band above POTS

(This annex forms an integral part of this Recommendation)

This annex defines those parameters of the ADSL system with extended upstream bandwidth that have been left undefined in the body of this Recommendation because they are unique to an ADSL service that is frequency-division duplexed with POTS.

M.1 ATU-C functional characteristics (pertains to clause 8)

M.1.1 ATU-C control parameter settings

The ATU-C control parameter settings to be used in the parameterized parts of the main body and/or to be used in this annex are listed in Table M.1. Control parameters are defined in clause 8.5.

Table M.1 – ATU-C control parameter settings

Parameter	Default setting	Characteristics
NSCds	512	
NOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.
MAXNOMATPds (operation per clause M.1.2)	20.4 dBm	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause 8.13.2.

M.1.2 ATU-C downstream transmit spectral mask for overlapped spectrum operation (supplements clause 8.10)

The ATU-C transmit spectral mask shall be identical to the ATU-C transmit spectral mask for overlapped spectrum operation over POTS, as defined in Figure A.1.

The passband is defined as the band from 25.875 to 2208 kHz and is the widest possible band used (i.e., implemented with overlapped spectrum). Limits defined within the passband apply also to any narrower bands used.

The low-frequency stopband is defined as frequencies below 25.875 kHz, the high-frequency stopband is defined as frequencies greater than 2208 kHz.

M.1.2.1 Passband PSD and response

See clause A.1.2.1.

M.1.2.2 Aggregate transmit power

See clause A.1.2.2.

M.1.3 ATU-C downstream transmit spectral mask for non-overlapped spectrum operation (supplements clause 8.10)

The ATU-C transmit spectral mask shall be identical to the ATU-C transmit spectral mask for non-overlapped spectrum operation over ISDN, as defined in Figure B.2.

Adherence to this mask will, in many cases, result in improved upstream performance of the other ADSL systems in the same or adjacent binder group, with the improvement dependent upon the other interferers. This mask differs from the mask in clause M.1.2 only in the band below 254 kHz.

The passband is defined as the band from 254 to 2208 kHz. Limits defined within the passband apply also to any narrower bands used.

The low-frequency stopband is defined as frequencies below 254 kHz, the high-frequency stopband is defined as frequencies greater than 2208 kHz.

In addition, the maximum PSD level in the in 0-4 kHz band shall not exceed –97.5 dBm/Hz measured in a reference impedance of 100 ohms, and the aggregate transmit power in the 0-4 kHz band shall not exceed +15 dBrn measured in a reference impedance of 600 ohms.

M.1.3.1 Passband PSD and response

See clause B.1.2.1.

M.1.3.2 Aggregate transmit power

See clause B.1.3.2.

M.2 ATU-R functional characteristics (pertains to clause 8)

M.2.1 ATU-R control parameter settings

See clause M.2.1 of ITU-T G.992.3.

M.2.2 ATU-R upstream transmit spectral mask (supplements clause 8.10)

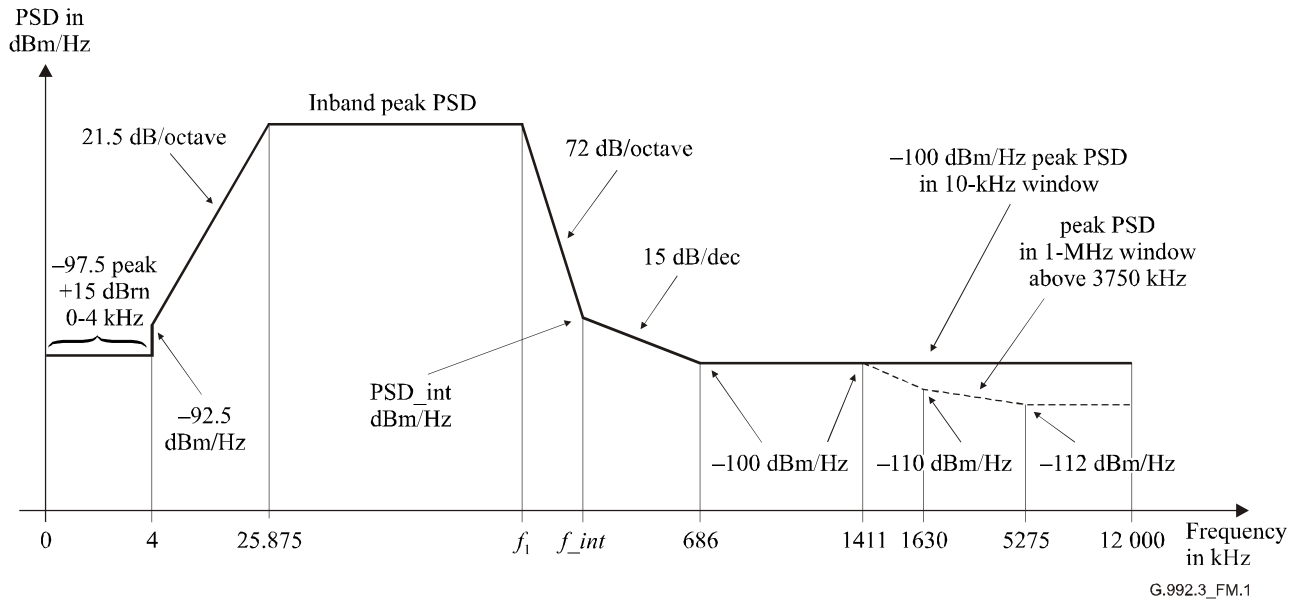
The ATU-R transmit PSD shall comply to one of the allowed family of spectral masks EU-32, EU-36, ... , EU-64 (see Note 1). Each of the spectral masks shall be as defined in Figure M.1 and Table M.3.

The passband is defined as the band from 25.875 kHz to an upperbound frequency *f*1, defined in Table M.3. It is the widest possible band used. Limits defined within the passband apply also to any narrower bands used.

Figure M.1 defines the family of ATU-R spectral masks for the transmit signal. The low-frequency stopband is defined as frequencies below 25.875 kHz, the high-frequency stopband is defined as frequencies greater than the passband upperbound frequency *f*1 defined in Table M.3. The *Inband_peak_PSD*, *PSD_int* and the frequencies *f*1 and *f_int* shall be as defined in Table M.3.

NOTE 1 – The ATU-R selects a transmit PSD mask from the family of upstream transmit PSD masks specified in Table M.3, based on the limitations imposed by the CO-MIB (which are exchanged during the ITU-T G.994.1 phase of initialization, see clause 8.13.2.4) and based on the capabilities of its transmit PMD function.

NOTE 2 – When deployed in the same cable as ADSL-over-POTS (Annex A/G.992.1, Annexes A & B of [b-ITU-T G.992.2], Annex A of [ITU-T G.992.3], Annex A of [b-ITU-T G.992.4] and Annex A of this Recommendation), there may be a spectral compatibility issue between the two systems due to the overlap of the Annex M upstream channel with the ADSL-over-POTS downstream channel at frequencies above 138 kHz. A detailed study of spectrum compatibility is referred to regional bodies. Deployment restrictions for systems using the upstream PSD masks defined in this annex may be imposed (e.g., by the regional regulatory authority).



Frequency (kHz)	PSD level (dBm/Hz)	Measurement BW
0	–97.5	100 Hz
4	–97.5	100 Hz
4	–92.5	100 Hz
10	Interpolated	10 kHz
25.875	*Inband_peak_PSD*	10 kHz
*f*1	*Inband_peak_PSD*	10 kHz
f_int	*PSD_int*	10 kHz
686	–100	10 kHz
5275	–100	10 kHz
12 000	–100	10 kHz

Additionally, the PSD mask shall satisfy the following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	Measurement BW
1411	–100	1 MHz
1630	–110	1 MHz
5275	–112	1 MHz
12 000	–112	1 MHz

NOTE 1 – All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.

NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.

NOTE 3 – MBW specifies the measurement bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency i.e., power in the [*f*, *f* + 1 MHz] window shall conform to the specification at frequency *f*.

NOTE 5 – The step in the PSD mask at 4 kHz is to protect ITU-T V.90 performance (see Figure A.1).

NOTE 6 – All PSD and power measurements shall be made at the U-R interface.

Figure M.1 – ATU-R transmitter PSD mask

Table M.3 – *Inband_peak_PSD*, *PSD_int* and the frequencies *f*1 and *f_int*

Upstream mask number	Desig-nator	Template nominal PSD (dBm/Hz)	Template maximum aggregate transmit power (dBm)	Inband peak PSD (dBm/Hz)	Frequency *f*1 (kHz)	Intercept frequency *f_int* (kHz)	Intercept PSD level *PSD_int* (dBm/Hz)
1	EU-32	–38.0	12.5	–34.5	138.00	242.92	–93.2
2	EU-36	–38.5	12.62	–35.0	155.25	274.00	–94.0
3	EU-40	–39.0	12.66	–35.5	172.50	305.16	–94.7
4	EU-44	–39.4	12.75	–35.9	189.75	336.40	–95.4
5	EU-48	–39.8	12.78	–36.3	207.00	367.69	–95.9
6	EU-52	–40.1	12.87	–36.6	224.25	399.04	–96.5
7	EU-56	–40.4	12.94	–36.9	241.50	430.45	–97.0
8	EU-60	–40.7	12.97	–37.2	258.75	461.90	–97.4
9	EU-64	–41.0	12.98	–37.5	276.00	493.41	–97.9
NOTE – The aggregate transmit power shall be limited for all PSD masks as defined in clause M.2.2.2.							

The upstream spectrum bounds default settings in Table M.2 apply for all EU-x and shaped PSD masks. Clause 8.13.2.4 defines how the ATU-R is to resolve inconsistencies between the upstream spectrum bounds, spectrum shaping and MIB PSD mask parameters contained in the CLR and CL messages.

In particular:

1) *NOMPSDus* shall be changed from its default value for the EU/ADLU masks 36 up to 64 during the preactivation (ITU-T G.994.1 phase, see clause clause 8.13.2) at least to the template nominal PSD values listed in Table M.3.

2) *MAXNOMPSDus* shall be a value within the Limit_PSD_Mask for PSD shaping (Table M.10) minus 3.5 dB.

M.2.2.1 Passband PSD and response

See clause I.2.2.1.

For spectrum management purposes, the PSD template is defined in Tables M.4 and M.5 (informative).

Table M.4 – ATU-R transmit PSD template definition

Frequency (kHz)	PSD level (dBm/Hz)
0	–101
4	–101
4	–96
25.875	*Inband_peak_PSD* –3.5 dB
*f*1	*Inband_peak_PSD* –3.5 dB
f_int _templ	*PSD_int_templ*
686	–100
1411	–100
1630	–110
5275	–112

12000	–112

Table M.5 – The *f_int_templ* and *PSD_int_templ* values for the ATU-R transmit PSD template

Upstream mask number	Designator	Template intercept frequency *f_int_templ* (kHz)	Template intercept PSD level *PSD_int_templ* (dBm/Hz)
1	EU-32	234.34	–93.0
2	EU-36	264.33	–93.8
3	EU-40	294.39	–94.5
4	EU-44	324.52	–95.1
5	EU-48	354.71	–95.7
6	EU-52	384.95	–96.2
7	EU-56	415.25	–96.7
8	EU-60	445.59	–97.2
9	EU-64	475.99	–97.6

M.2.2.2 Aggregate transmit power

See clause M.2.2.2 of ITU-T G.992.3.

M.3 Initialization

The ATU-C and ATU-R shall support all upstream PSD masks listed in Table M.3.

M.3.1 Handshake – ATU-C (supplements clause 8.13.2.1)

The ITU-T G.994.1 codepoints required for the initialization of ATU-C and ATU-R shall be contained in an "Annex M submode PSD masks" SPAR(2) parameter block. This parameter block shall be added to the ITU-T G.994.1 codetree defined for this annex (specific requirements for an ADSL system with extended upstream bandwidth, operating in the frequency band above POTS).

M.3.1.1 CL messages (supplements clause 8.13.2.1.1)

See clause M.3.1.1 of ITU-T G.992.3.

M.3.1.2 MS messages (supplements clause 8.13.2.1.2)

See clause M.3.1.2 of ITU-T G.992.3.

M.3.2 Handshake – ATU-R (supplements clause 8.13.2.2)

The ITU-T G.994.1 codepoints required for the initialization of ATU-C and ATU-R shall be contained in an "Annex M submode PSD masks" SPAR(2) parameter block. This parameter block shall be added to the ITU-T G.994.1 codetree defined for this annex (specific requirements for an ADSL system with extended upstream bandwidth, operating in the frequency band above POTS).

M.3.2.1 CLR messages (supplements clause 8.13.2.2.1)

See clause M.3.2.1 of ITU-T G.992.3.

M.3.2.2 MS messages (supplements clause 8.13.2.2.2)

See clause M.3.2.2 of ITU-T G.992.3.

M.3.3 Spectral bounds and shaping parameters (supplements clause 8.13.2.4)

In the CLR message, the ATU-R shall indicate all supported PSD masks. The CLR message may include the upstream spectral shaping (tss_i) and upstream spectrum bounds information of the preferred upstream PSD mask.

In the CL message, the ATU-C shall indicate the selected mode. The CL message may include the upstream spectral shaping (tss_i) and spectrum bounds information of the selected mode.

If the upstream spectrum bounds and shaping parameters of the CLR message, and the PSD mask selection in the CL message, are found to be inconsistent, then the ATU-R shall do either of the following:

- The ATU-R sends an MS message indicating that it is not prepared to select a mode at this time (according to clause 10.1.1 of [ITU-T G.994.1]). After termination of the ITU-T G.994.1 session, the ATU-R calculates new upstream spectrum bounds and shaping parameters offline, taking into account the upstream spectrum bounds, shaping parameters and PSD mask specified by the ATU-C in the CL message of the previous ITU-T G.994.1 session. In a subsequent ITU-T G.994.1 session, the ATU-R sends a CLR message including the new spectrum bounds and shaping parameters corresponding to the selected PSD mask.
- The ATU-R calculates new upstream spectrum bounds and shaping parameters online, taking into account the upstream spectrum bounds, shaping parameters and PSD mask specified by the ATU-C in the CL message. In the same ITU-T G.994.1 session, the ATU-R repeats the CLR/CL exchange transaction with a CLR message including the new spectrum bounds and shaping parameters corresponding to the selected PSD mask.

M.3.4 Upstream spectrum shaping

See clause M.3.4 of ITU-T G.992.3, adding the following text at the beginning of this clause.

The upstream spectrum shaping for this annex is defined in the same way as for Annex M of [ITU-T G.992.3]. The difference with clause M.3.4 of [ITU-T G.992.3] is the handshake codepoints being identically defined but added under the Spar(1) codetree relating to this annex.

M.4 Electrical characteristics

The ATU shall meet the electrical characteristics defined in clause A.4.

The ATU-C longitudinal conversion loss (LCL) requirements shall apply over the frequency ranges from 30 kHz to 276 kHz and from 276 kHz to 1104 kHz, respectively.

The ITU-T G.992.3 requirements (except longitudinal conversion loss) applying over a frequency band up to 1104 kHz shall be met over a frequency band up to 2208 kHz.

The longitudinal conversion loss (LCL) requirements in the frequency range from 1104 kHz to 2208 kHz are defined in clause A.4.

NOTE – Softbank BB (Japan), Conexant Systems (USA) and UT Starcom (USA), in line with the provisions of clause 5.5 of Recommendation ITU-T A.8, registered a degree of concern with regard to Annex M. Their concern is:

> "Today, there are over 60 million lines of ADSL deployed worldwide based on Annex A. If ADSL systems based on Annex M are deployed in the same cable with Annex A-based systems, the service quality of existing ADSL systems may become significantly degraded. The impact of high volume deployment of Annex M-based systems has not been thoroughly evaluated or considered. Proper definition of Annex M should be such that it can be deployed on a worldwide volume basis."

Annex N

This annex is intentionally left blank

Annex O

This annex is intentionally left blank

Annex P

Reduced downstream aggregate transmit power requirements

(This annex forms an integral part of this Recommendation)

See Annex P of ITU-T G.992.3.

Appendix I

ATM layer to physical layer logical interface

(This appendix does not form an integral part of this Recommendation)

See Appendix I of ITU-T G.992.3.

Appendix II

Compatibility with other customer premises equipment

(This appendix does not form an integral part of this Recommendation)

See Appendix II of ITU-T G.992.3.

Appendix III

The impact of primary protection devices on line balance

(This appendix does not form an integral part of this Recommendation)

See Appendix III of ITU-T G.992.3.

Appendix IV

PSD template to be used in capacity calculations with in-band transmit spectrum shaping

(This appendix does not form an integral part of this Recommendation)

This appendix describes the PSD template to be used in capacity calculations for cases where in-band transmit spectrum shaping (tss_i) is applied.

This appendix supports the possibility for downstream spectrum control with individual maximum transmit PSD at the U-C reference point per subcarrier, under operator control through the CO-MIB (see clause 8.5.1), to allow configuration per regional requirements (e.g., North America, Europe or Japan) and deployment scenarios (e.g., CO or remote). The downstream spectrum is controlled via the control parameter *MIB_PSD_mask(f)* (see clause 8.5.1). The parameter *MIB_PSD_mask(f)* defines the PSD mask at the U-C reference point. The average PSD at the U-C reference point is given by *MIB_PSD_template(f)* (see clause 8.5.1). The inband part of the CO-MIB specified PSD mask (the part with the *MAXINSLOPE*) will typically be realized by adjusting the gain values of individual subcarriers using the tss_i values.

In capacity calculations, capacity depends on the transmit power on each individual subcarrier. This power is proportional to the squared tss_i value.

For a flat PSD template, the tss_i gain values are equal to 1 (assuming ideal flat time-domain filtering, DAC and AFE) and, therefore, the transmit power on each subcarrier can be directly calculated from the *MIB_PSD_template*.

However, it should be noted that, if the inband part is non-flat shaped, it cannot be assumed that the tss_i gain values exactly follow the shape of the *MIB_PSD_template*. In other words, it cannot be assumed that the tss_i values equal the value *MIB_PSD_template(i) – NOMPSD*. This is because the side lobes of higher power subcarriers will increase the PSD of lower power carriers as measured at the U-C reference point.

For this reason, an equivalent PSD template shall be defined for the purpose of capacity calculations, incorporating the transmit spectrum shaping tss_i:

$$Capacity\_PSD\_template(i) = powergain\_DAC\&AFE \times tss_i2(i)$$

The tss_i values can be calculated using:

$$MIB\_PSD\_template\_dB(f) = MIB\_PSD\_mask\_dB(f) - 3.5 \text{ dB}$$

$$MIB\_PSD\_template\_(i) = 10\hat{\ }(MIB\_PSD\_template\_dB(i.\Delta f)/10)$$

$$\text{for } n\_IB\_low\_MIB \le i \le n\_IB\_high\_MIB$$

$$tss_i2 = A^{-1} \times MIB\_PSD\_template/powergain\_DAC\&AFE$$

Alternatively, one can directly calculate:

$$Capacity\_PSD\_template(i) = A^{-1} \times MIB\_PSD\_template$$

where:

- tss_i2 is the vector of the squared values of tss_i, i.e., $tss_i(i)$^2.
- A^{-1} is the inverse of matrix A.

- A is the matrix:

$$A(m,n)=\left(1/K\right)\times\frac{17}{16}\times\operatorname{sin}c\left(\frac{17}{16}\times(m-n)\right)^{\wedge}2$$

for $n\_IB\_low\_MIB \le m \le n\_IB\_high\_MIB$, $n\_IB\_low\_MIB \le n \le n\_IB\_high\_MIB$

$$\text{with } K=\sum\frac{17}{16}\times\operatorname{sin}c\left(\frac{17}{16}\times i\right)^{\wedge}2=1.1162=0.48\,\text{dB}$$

- *n_IB_low_MIB* is the first tone of the inband part of the CO-MIB PSD mask.

  Using the definitions in clause 8.5.1:

  n_IB_low_MIB = t_1 if t_1 = *roundup(f_pb_start/Δf)*

  n_IB_low_MIB = t_2 if $100 \le t_1 \le 256$

- *n_IB_high_MIB* is the last tone of the inband part of the CO-MIB PSD mask.

  Using the definitions in clause 8.5.1:

  n_IB_high_MIB = tN

Capacity calculations should use the equivalent PSD template on each individual subcarrier as calculated by *Capacity_PSD_template.*

Appendix V

Constraints on delay, impulse noise protection, overhead rate, and net data rate when bonding

(This appendix does not form an integral part of this Recommendation)

This appendix considers the case when multiple transceivers form a bonding group, and the differential delay among members of the group, are controlled through the *delay_min* parameter derived from [ITU-T G.994.1]. This appendix outlines a set of simple rules that allows the construction of a valid set of configuration parameters involving the minimum delay (*delay_min*), the minimum impulse noise protection (*INP_min*), the minimum overhead message rate (*MSGmin*), the minimum net data rate (*net_min*) and the data rate granularity. These rules restrict the framing parameters and may lead to a reduction in the attainable data rates.

The rules are as follows:

- Set *delay_min* = *delay_max*. In either the upstream or downstream direction, all transceivers in a bonding group should use the same delay. In the downstream direction, a value for delay can be selected from either Table V.1 or Table V.2. When using delays from Table V.2, since the internal representation of *delay_min* and *delay_max* are restricted to integers, *delay_min* should be set to floor(*delay_min*) and *delay_max* should be set to ceil(*delay_max*) where floor(·) and ceil(·) are the 'greatest integer less than' and 'smallest integer greater than', respectively. In the upstream direction, *delay_min* and *delay_max* should be selected from Table V.3.
- Set the minimum net data rate below the values shown in Table V.1 or Tables V.2 and V.3 for downstream and upstream, respectively. Depending on the downstream PSD mask and value of *BIMAX*, the actual maximum net data rate might be lower than those shown in these tables.
- Depending on the delay, the valid range of *MSGmin* and the corresponding data rate granularity (minimum value of *net_max* – *net_min*) are listed in Tables V.4 and V.5.

Table V.1 – Maximum downstream net data rate (kbit/s) for various values of *delay_min* = *delay_max* and *INP_min*

		INP_min (Note 2)						
		0	**½**	**1**	**2**	**4**	**8**	**16**
***delay_min* *delay_max* (ms)**	**1 (Note 1)**	24432	0	0	0	0	0	0
	2	16256	7104	3008	960	0	0	0
	4	16256	15232	7104	3008	960	0	0
	8	16256	15232	15232	7104	3008	960	0
	16	8064	7552	7552	7552	3520	1472	448
	32	3968	3712	3712	3712	3712	1728	704
NOTE 1 – In [ITU-T G.997.1], a 1 ms delay is reserved to mean that $S_p \leq 1$ and $D_p = 1$. NOTE 2 – Values of *INP_min* in grey are optional.								

Table V.2 – Maximum downstream net data rate (kbit/s) for various values of *delay_min* = *delay_max* and *INP_min*

		***INP_min* (Note 2)**						
		0	**½**	**1**	**2**	**4**	**8**	**16**
delay_min *delay_max* (ms)	**1.33 (Note 1)**	24432	6576	2448	432	0	0	0
	2.67 (Note 1)	24432	14736	6576	2448	432	0	0
	5.33 (Note 1)	24432	22896	14736	6576	2448	432	0

NOTE 1 – Set delay_max = ceil(delay) and delay_min = floor(delay).
NOTE 2 – Values of INP_min in grey are optional.

Table V.3 – Maximum upstream net data rate (kbit/s) for various values of *delay_min* = *delay_max* and *INP_min*

		***INP_min* (Note 2)**						
		0	**½**	**1**	**2**	**4**	**8**	**16**
***delay_min* *delay_max* (ms)**	**1 (Note 1)**	3520	0	0	0	0	0	0
	2	3520	3072	1472	448	0	0	0
	4	3520	3264	1728	704	192	0	0
	8	1920	1792	1792	832	320	64	0
	16	896	832	832	832	384	128	0
	32	0	0	0	0	0	0	0

NOTE 1 – In [ITU-T G.997.1], a 1 ms delay is reserved to mean that $S_p \leq 1$ and $D_p = 1$.
NOTE 2 – Values of *INP_min* in grey are optional.

Table V.4 – Range of *MSGmin* and minimum data rate granularity (*net_max* – *net_min*) when delay is selected from Table V.1 or V.3

***MSGmin* (kbit/s)**	**Data rate granularity (kbit/s)**
60-64	Not supported
29-59	64
14-28	32
6-13	16
4-5	8

Table V.5 – Range of *MSGmin* and minimum data rate granularity (*net_max* – *net_min*) when delay is selected from Table V.2

***MSGmin* (kbit/s)**	**Data rate granularity (kbit/s)**
45-64	Not supported
21-44	48
9-20	24
4-8	12

Appendix VI

Packet layer to physical layer logical interface

(This appendix does not form an integral part of this Recommendation)

See Appendix VI of ITU-T G.992.3.

Appendix VII

ADSL2plus automoding

(This appendix does not form an integral part of this Recommendation)

See Appendix VII of ITU-T G.992.3.

Appendix VIII

Impact of loop and ATU impedance mismatch on the Hlog accuracy

(This appendix does not form an integral part of this Recommendation)

See Appendix VIII of ITU-T G.992.3.

Bibliography

[b-ITU-T G.995.1] Recommendation ITU-T G.995.1 (2001), *Overview of digital subscriber line (DSL) Recommendations*.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	**Transmission systems and media, digital systems and networks**
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Terminals and subjective and objective assessment methods
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects and next-generation networks
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2010