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

Digital sections and digital line system – Access networks

Splitterless asymmetric digital subscriber line transceivers 2 (splitterless ADSL2)

ITU-T Recommendation G.992.4

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ITU-T Recommendation G.992.4

Splitterless asymmetric digital subscriber line transceivers 2 (splitterless ADSL2)

Summary

This Recommendation describes the interface between the telecommunications network and the customer installation in terms of their interaction and electrical characteristics. G.992.4 allows the transmission of POTS and V-series data services simultaneously with a digital channel over a single mixed gauge twisted metallic pair. Operation in a TCM-ISDN noise environment is for further study. This Recommendation is structured as a delta document to ITU-T Rec. G.992.3.

This Recommendation includes procedures to allow provisioning without the need for "splitters", typically installed at the ingress to the customer premises. Additionally, power management procedures and link states are specified to achieve power savings at the central office and customer premises.

This Recommendation describes the second generation of splitterless ADSL, based on the first generation ITU-T Rec. G.992.2. This Recommendation may be easily implemented in multi-mode devices that support both G.992.4 and G.992.2 with the following major additions and revisions:

- Improved application support for an all digital mode of operation and voice over ADSL operation.
- A new packet TPS-TC function and a STM TPS-TC function in addition to the existing ATM support.
- Support for IMA in the ATM TPS-TC.
- Improved configuration capability for each TPS-TC with configuration of latency, BER and minimum, maximum and reserve data rate.
- New line diagnostic procedures available for both successful and unsuccessful initialization scenarios.
- Enhanced on-line reconfiguration capabilities including bit-swaps, dynamic rate repartitioning, and seamless rate adaptation.
- A more flexible TPS-TC function including support for up to 4 frame bearers, 4 latency paths, and control parameters allowing enhanced configuration of the overhead channel.
- Performance improvements including mandatory support for R = 16, one-bit constellations, and trellis coding.
- A more robust initialization procedure that includes splitterless capability features of the G.992.2 fast retrain procedure, CO and CP controlled adaptive signal durations, receiver determined adaptive frequency modulation for data exchange, and an optional adaptive length fast start-up procedure.
- Improved RFI and spectrum management tools including transmit power cutback at both ends of the line, spectrum shaping, sub-carrier black-out lists to avoid RFI, and improved sub-carrier ordering to help mitigate the propagation of RFI from sub-carrier to sub-carrier.
- Power saving features including mandatory reduction of excess margin under management layer control and a new L2 power management link state with low power features for the central office.

Source

ITU-T Recommendation G.992.4 was prepared by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 29 July 2002.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. 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.

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 received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

ITU-T Recommendation G.992.4

Splitterless asymmetric digital subscriber line transceivers 2 (splitterless ADSL2)

1 Scope

This Recommendation describes the interface between the telecommunications network and the customer installation in terms of their interaction and electrical characteristics. The requirements of this Recommendation apply only to a single asymmetric digital subscriber line (ADSL). ADSL allows the provision of voiceband services, including POTS and V-series data services, and a number of digital channels. This Recommendation is structured as a delta document to ITU-T Rec. G.992.3.

The transmission system is designed to operate on mixed gauge two-wire twisted metallic pairs over the existing copper facilities and over the customer premises wiring. The transmission system is based on the use of loop plant cables without loading coils. Bridged taps in the loop plant are acceptable in all but a few unusual situations.

Operation in a TCM-ISDN noise environment is for further study.

An overview of Digital Subscriber Line Transceivers can be found in ITU-T Rec. G.995.1.

This Recommendation describes the second generation of splitterless ADSL, based on the first generation ITU-T Rec. G.992.2. This Recommendation is easily implemented in multi-mode devices that support both G.992.4 and G.992.2 with the following major additions or revisions:

- Improved application support for an all digital mode of operation and voice over ADSL operation.
- A new packet TPS-TC function and a STM TPS-TC function in addition to the existing ATM support.
- Support for IMA in the ATM TPS-TC.
- Improved configuration capability for each TPS-TC with configuration of latency, BER and minimum, maximum and reserve data rate.
- New line diagnostic procedures available for both successful and unsuccessful initialization scenarios.
- Enhanced on-line reconfiguration capabilities including bit-swaps, dynamic rate repartitioning, and seamless rate adaptation.
- A more flexible TPS-TC function including support for up to 4 frame bearers, 4 latency paths, and control parameters allowing enhanced configuration of the overhead channel.
- Performance improvements including mandatory support for R = 16, one-bit constellations, and trellis coding.
- A more robust initialization procedure that includes splitterless capability features of the G.992.2 fast retrain procedure, CO and CP controlled adaptive signal durations, receiver determined adaptive frequency modulation for data exchange, and an optional adaptive length fast start-up procedure.
- Improved RFI and spectrum management tools including transmit power cutback at both ends of the line, spectrum shaping, sub-carrier black-out lists to avoid RFI, and improved sub-carrier ordering to help mitigate the propagation of RFI from sub-carrier to sub-carrier.
- Power saving features including mandatory reduction of excess margin under management layer control and a new L2 mode with low power features for the central office.

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 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

[1] ITU-T Recommendation G.994.1 (2002), *Handshake procedures for Digital Subscriber Line (DSL) transceivers.*

[2] ITU-T Recommendation G.992.3 (2002), *Asymmetric Digital Subscriber Line transceivers 2 (ADSL2).*

[3] ITU-T Recommendation G.997.1 (1999), *Physical layer management for Digital Subscriber Line (DSL) transceivers.*

3 Definitions

The definitions in clause 3/G.992.3 shall apply for this Recommendation.

4 Abbreviations

The abbreviations in clause 4/G.992.3 shall apply for this Recommendation.

5 Reference models

G.992.4 devices fit within the XDSL Recommendations described in ITU-T Rec. G.995.1. Additionally, G.992.4 devices rely upon constituent components described within ITU-T Recs G.994.1 and G.997.1. This clause provides the necessary functional, application, and protocol reference models so that the subclauses of G.992.4 may be related to these additional Recommendations.

5.1 ATU functional model

The ATU functional model for G.992.4 shall be identical to that provided in 5.1/G.992.3. Figure 5-1/G.992.3 is duplicated here for reference.

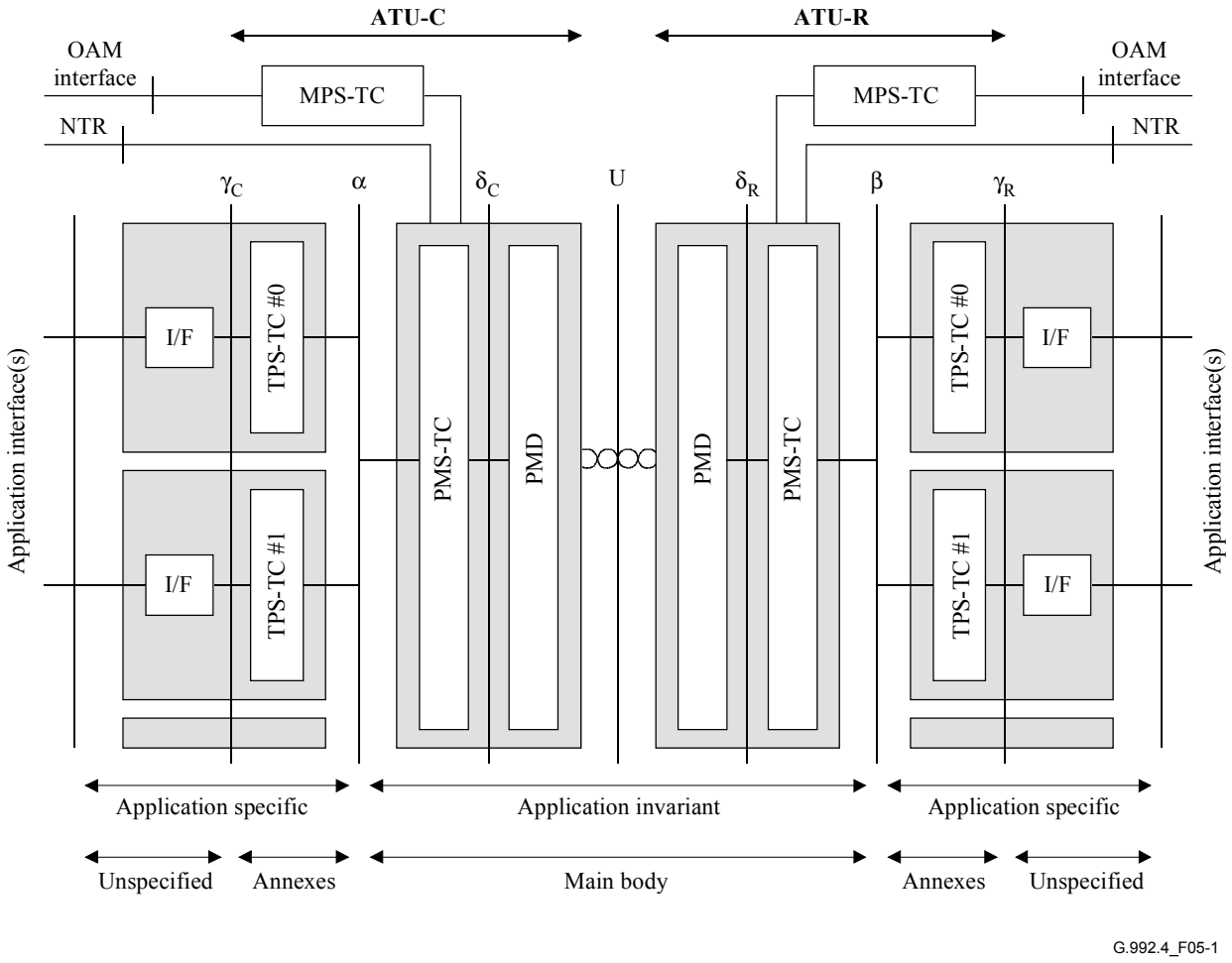


Figure 5-1/G.992.4 – ATU functional model

5.2 User plane protocol reference model

The user plane protocol reference model of G.992.4 shall be as defined in 5.2/G.992.3. Figure 5-2/G.992.3 is duplicated here for reference.

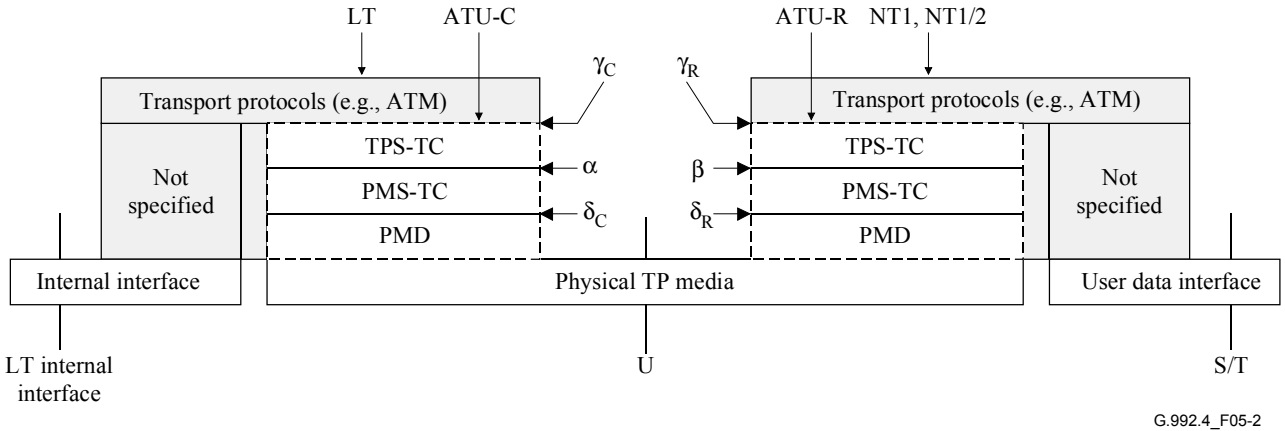


Figure 5-2/G.992.4 – User plane protocol reference model

5.3 Management plane reference model

The management plane protocol reference model of G.992.4 shall be as defined for G.992.3 in 5.3/G.992.3. Figure 5-3/G.992.3 is duplicated here for reference.

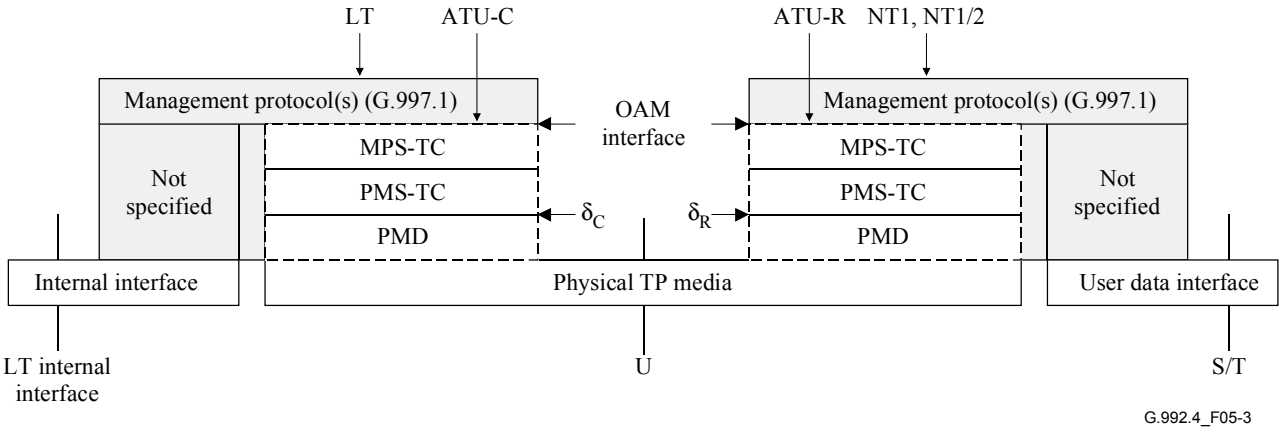


Figure 5-3/G.992.4 – Management plane protocol reference model

5.4 Application models

The application models for G.992.4 are based upon the generic reference configuration described in 6.1/G.995.1 as are the application models for G.992.3. The two generic application models defined in 5.4/G.992.3 shall be used for G.992.4. Figure 5-5/G.992.3 is duplicated here for reference. This application model for remote splitterless deployment is intended to be used more prevalently with G.992.4.

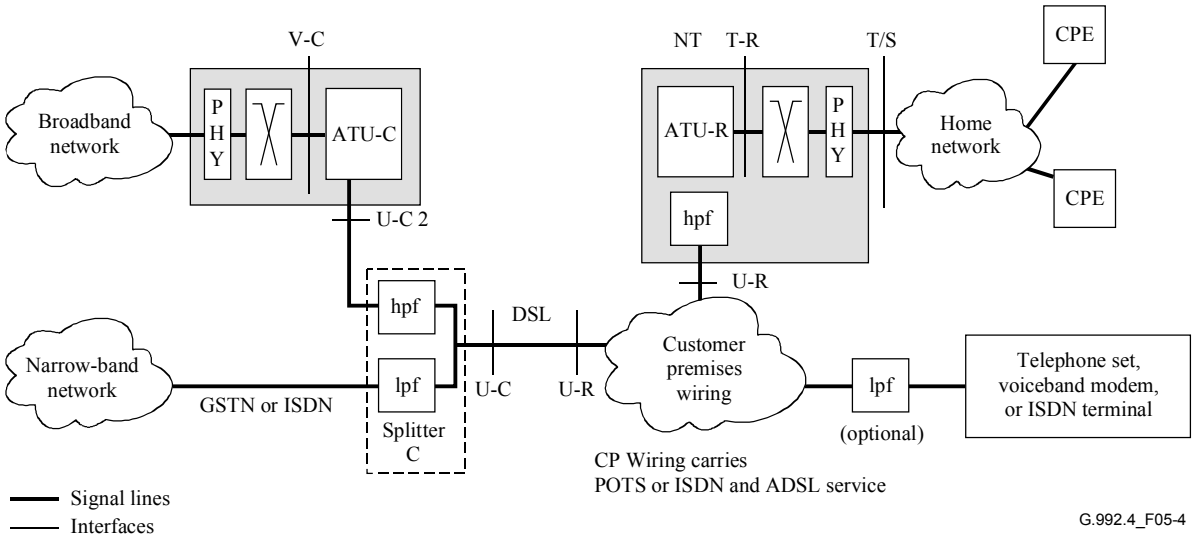


Figure 5-4/G.992.4 – Generic application reference model for splitterless remote deployment

5.4.1 Data service

The application model of G.992.4 for delivering data service is the same as the application model defined in 5.4.1/G.992.3.

5.4.2 Data with POTS service

The application model of G.992.4 for delivering data with POTS service of G.992.4 is the same as the application model defined in 5.4.2/G.992.3.

5.4.3 Intentionally left blank

This heading and section are intentionally left void to facilitate alignment of the G.992.4 and G.992.3 table of contents.

5.4.4 Voice over data service

The application model for delivering voice and data over G.992.4 is the same as the application model defined in 5.4.4/G.992.3.

6 Transport Protocol Specific Transmission Convergence (TPS-TC) function

This Recommendation provides procedures for the transport of the frame bearers of one to four unidirectional TPS-TC functions in both the upstream and downstream directions. The ATU TPS-TC transport capabilities and functions, interfaces, and procedures shall be as defined in clause 6/G.992.3 and appropriate subclauses of Annex K/G.992.3.

The control parameters of the TPS-TC function shall be as defined in Table 6-1/G.992.3 and appropriate subclauses of Annex K/G.992.3. The valid control parameter values shall be as defined in 6.3.1/G.992.3, and the valid control settings shall be as defined in 6.3.2/G.992.3 except that mandatory control settings for the TPS-TC shall be limited and shall not exceed a net downstream data rate (referenced to the input of the PMS-TC function) of 1.536 Mbit/s and a net upstream data rate of 512 kbit/s. Support for data rates above the mandatory rates is optional and allowed.

The G994.1 CL and MS information formats for the TPS-TC function shall be as defined in Table 6-2/G.992.3 and appropriate subclauses of Annex K/G.992.3. During all G.994.1 message, the bit(s) corresponding to supporting G.992.4 annexes shall be asserted.

7 Physical Media Specific Transmission Convergence (PMS-TC) function

The primary purpose of the ATU PMS-TC function is to provide for the multiplexing and transport of several channels of information. The ATU PMS-TC transport capabilities and functions, interfaces, control variables, and procedures shall be as defined in clause 7/G.992.3 with the following exceptions or clarifications in specific subclauses.

Subclause 7.8.1	References in G.992.3 to a sample clock of 2.208 MHz shall be replaced with 1.104 MHz for G.992.4. Similarly, reference to 453 ns in G.992.3 shall be replaced with 905 ns for G.992.4
Subclause 7.10.1	During all G.994.1 message, the SPAR(1) bit(s) corresponding to supported G.992.4 Annex(es) shall be asserted.
Subclause 7.12.1.1	The upper bound on the value of $\sum L_p$ shall be less than or equal to 192.

8 Physical Media Dependent (PMD) function

The primary purpose of the ATU Physical Media Dependent (PMD) function is to provide for the transport of a bitstream over the physical medium (i.e., over the copper pairs) in both the upstream and downstream directions. The ATU PMD transport capabilities and functions, interfaces, control variables, and procedures shall be as defined in clause 8/G.992.3 with the following exceptions or clarifications in specific subclauses.

Subclause 8.5.1	The value of the control parameter NSCds shall be as defined in the annexes of this Recommendation. The number of downstream sub-carrier defined in those annexes shall be used when a G.994.1 SPAR(1) bit corresponding to the annex is asserted in a MS command.
Subclause 8.10	The transmitter spectral masks for the different service options are defined in annexes of this Recommendation. The maximum passband PSD, maximum stopband PSD and maximum aggregate transmit power defined in those annexes shall be used when the G.994.1 SPAR(1) bit corresponding to the annex is asserted in a MS command.
Subclause 8.13.2	During all G.994.1 message, the SPAR(1) bit(s) corresponding to supported G.992.4 annex(es) shall be asserted.
Subclause 8.13.2.1.1	The NPAR(2) bit corresponding to Tones 1-32 shall be ignored.
Subclause 8.13.2.1.2	The NPAR(2) bit corresponding to Tones 1-32 shall be ignored.
Subclause 8.13.2.2.1	The NPAR(2) bit corresponding to Tones 1-32 shall be ignored.
Subclause 8.13.2.2.2	The NPAR(2) bit corresponding to Tones 1-32 shall be ignored.
Subclause 8.13.3.1.2	The sub-carriers used for C-COMB symbols shall be limited to those below NSCds.
Subclause 8.13.5.1.4	The sub-carriers used for C-MEDLEY shall be limited to those below NSCds, and the data pattern used to create symbols shall be the same as in G.992.3. 256 bit-pairs shall be extracted from the PRBS generator every symbol, but the bits corresponding to all sub-carriers above NSCds-1 shall be effectively ignored.
Subclause 8.13.6.2.1	The data exchanged in R-MSG2 message shall be limited to sub-carriers below NSCds. The R-MSG2 message bits corresponding to all sub-carrier above NSCds-1 shall be set to zero and ignored by the receiver. The length of the R-MSG2 message of G.992.4 is the same as G.992.3.

9 Management Protocol Specific Transmission Convergence (MPS-TC) functions

The primary purpose of the ATU MPS-TC function is to provide for the transport of a clear eoc and command messages. Additionally, the MPS-TC controls the implementation of power management modes. The ATU MPS-TC transport capabilities and functions, interfaces, and procedures shall be as defined in clause 9/G.992.3 with the following exceptions or clarifications in specific subclauses.

Subclause 9.4.1.10	The number of sub-carriers shall be NSC. The test parameters that have per sub-carriers values shall only return values related to sub-carriers NSC.

10 Control Protocol Specific Transmission Convergence (CPS-TC) functions

The control reference model of G.992.4 is for further study.

11 Dynamic behaviour

The ATUs contain several dynamic behaviours, including initialization, power management, and on-line reconfiguration. These shall be as described in clause 10/G.992.3.

Annex A

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

This annex defines parameters that have been left unspecified in the body of this Recommendation because they are specific to an ADSL service that is frequency-division duplexed with and over POTS.

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

A.1.1 ATU-C PMD control parameter settings

The ATU-C PMD Control Parameter Settings shown in Table A.1 shall be as shown in that table in accordance with the definitions in clause 8. All the values except NSCds may be changed relative to the shown value during G.994.1 as described in clause 8. The values that are different from G.992.3 are NSCds, and MAXNOMATPds.

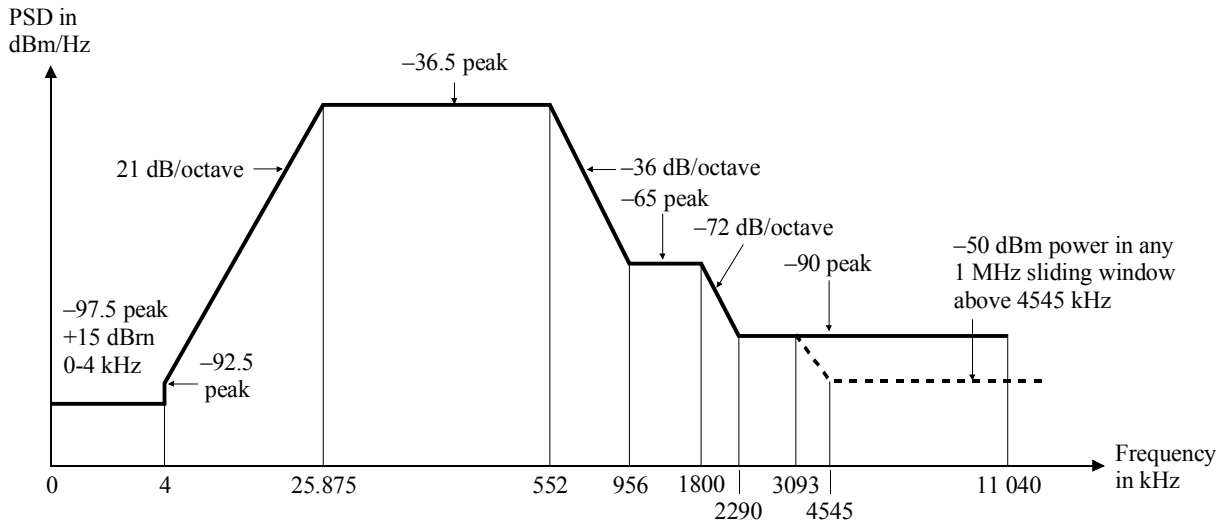
Table A.1/G.992.4 – ATU-C control parameter settings for the PMD transmit function

Parameter	Default setting	Characteristics
NSCds	128	
NOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during G.994.1 phase, see 8.13.2/G.992.3.
MAXNOMPSDds	–40 dBm/Hz	Setting may be changed relative to this value during G.994.1 phase, see 8.13.2/G.992.3.
MAXNOMATPds	17.2 dBm	Setting may be changed relative to this value during G.994.1 phase, see 8.13.2/G.992.3.

A.1.2 ATU-C downstream transmit spectral mask for overlapped spectrum operation

The passband is defined differently than G.992.3 Annex A as the band from 25.875 to 552 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 spectral mask for the transmit signal. The low-frequency stop-band is defined as frequencies below 25.875 kHz and includes the POTS band, the high-frequency stop-band is defined as frequencies greater than 552 kHz.



Frequency band *f* (kHz)	Equation for line (dBm/Hz)
$0 < f < 4$	–97.5, with max power in the in 0-4 kHz band of +15 dBrn
$4 < f < 25.875$	$-92.5 + 21 \times \log_2 (f/4)$
$25.875 < f < 552$	–36.5
552-956	$-36.5 - 36 \times \log(f/552)/\log(2)$
956-1800	–65
1800-2290	$-65 - 72 \times \log(f/1800)/\log(2)$
2290-3093	–90
$3093 < f < 4545$	–90 peak, with max power in the $[f, f + 1$ MHz] window of $(-36.5 - 36 \times \log_2(f/1104) + 60)$ dBm
$4545 < f < 11\ 040$	–90 peak, with max power in the $[f, f + 1$ MHz] window of –50dBm

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.

NOTE 3 – Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.

NOTE 5 – The step in the PSD mask at 4 kHz is to protect 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 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 (see Figure 5-4).

G.992.4_FA-1

Figure A.1/G.992.4 – ATU-C transmitter PSD mask for overlapped spectrum operation

A.1.2.1 Passband PSD and response

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 PSD template nominal passband transmit PSD level is –40 dBm/Hz.

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 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 Rec. 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 implementation tolerances, and not exceed 17.7 dBm.
- the aggregate transmit power over the 0 to 11.04 MHz band shall not exceed (MAXNOMATPds-PCBds) by more than 0.9 dB, in order to account for residual transmit power in the stop bands and implementation tolerances.

For spectrum management purposes, the PSD template nominal passband aggregate transmit power is 17.2 dBm.

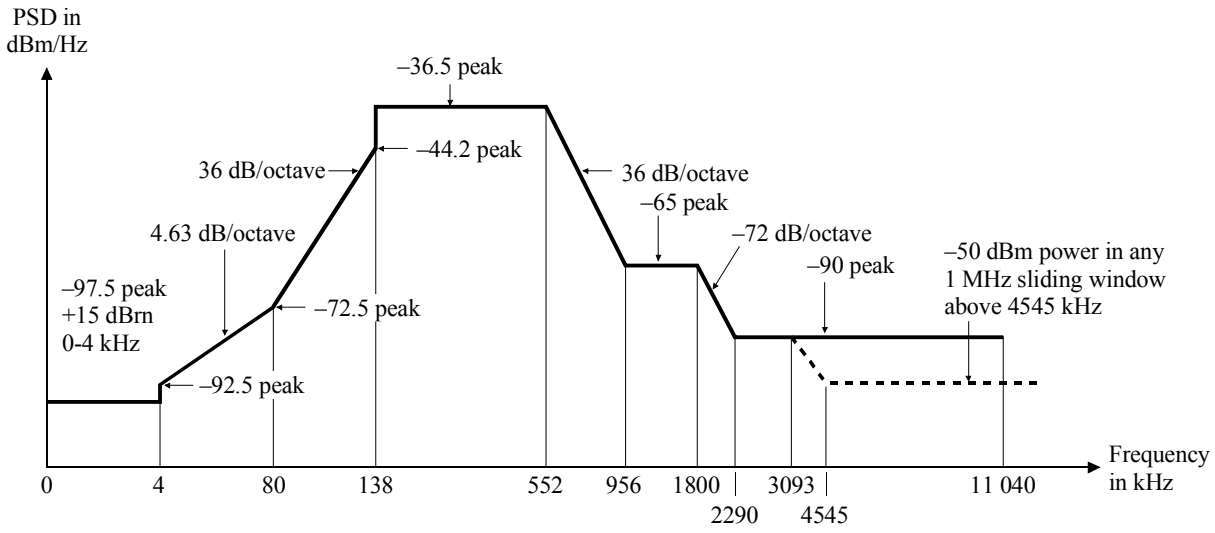
The power emitted by the ATU-C is limited by the requirements in this subclause. Notwithstanding these requirements, it is assumed that the ADSL will comply with applicable national requirements on emission of electromagnetic energy.

A.1.3 ATU-C transmitter PSD mask for non-overlapped spectrum operation

Figure A.2 defines the spectral mask for the ATU-C transmitted signal, which results in reduced NEXT into the ADSL upstream band, relative to the mask in 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 A.1.2 only in the band from 4 kHz to 138 kHz.

The passband is defined as the band from 138 to 552 kHz. Limits defined within the passband apply also to any narrower bands used.

The low-frequency stop-band is defined as frequencies below 138 kHz and includes the POTS band, the high-frequency stop-band is defined as frequencies greater than 552 kHz.



Frequency band *f* (kHz)	Equation for line (dBm/Hz)
$0 < f < 4$	–97.5, with max power in the in 0-4 kHz band of +15 dBrn
$4 < f < 80$	$-92.5 + 4.63 \times \log_2 (f/4)$
$80 < f < 138$	$-72.5 + 36 \times \log_2 (f/80)$
$138 < f < 552$	–36.5
552-956	$-36.5 - 36 \times \log(f/552)/\log(2)$
956-1800	–65
1800-2290	$-65 - 72 \times \log(f/1800)/\log(2)$
2290-3093	–90
$3093 < f < 4545$	–90 peak, with max power in the [*f*,*f* + 1 MHz] window of $(-36.5 - 36 \times \log_2(f/1104) + 60)$ dBm
$4545 < f < 11\,040$	–90 peak, with max power in the [*f*,*f* + 1 MHz] window of –50 dBm

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.

NOTE 3 – Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.

NOTE 5 – The step in the PSD mask at 4 kHz is to protect 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 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 (see Figure 5-4).

G.992.4_FA-2

Figure A.2/G.992.4 – ATU-C transmitter PSD mask for non-overlapped spectrum operation

A.1.3.1 Passband PSD and response

Across the whole passband, the transmit PSD level shall not exceed the maximum passband transmit PSD level defined in A.1.2.1.

A.1.3.2 Aggregate transmit power

In all cases the aggregate transmit power shall meet the requirements defined in A.1.2.2, Aggregate transmit power. In addition, for non-overlapped spectrum operation, the aggregate transmit power across the whole passband shall not exceed 16.7 dBm.

For spectrum management purposes, the PSD template nominal passband aggregate transmit power is 16.2 dBm.

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

The ATU-R PMD control parameter settings, ARU-R upstream transmit spectram masks, ATU-R passband PSD and response, and ATU-R transmit aggregate transmit power shall conform to A.2/G.992.3.

A.3 Intentionally left blank

This heading and section are intentionally left void to facilitate alignment of the G.992.4 and G.992.3 table of contents.

A.4 Electrical characteristics

The requirements for ATU-R impedance states, ATU-R POTS current and voltage specifications, electrical characteristics of the ATU-R and ATU-C while in the active state, and electrical characteristics of the ATU-R while in high impedance state as defined in A.4/G.992.3 shall be satisfied. The impedance and passband requirements for this clause shall apply across the entire passband as defined for G.992.3 in A.4 (i.e., not only to the passband defined for this Recommendation).

Annex B

(void annex)

This annex heading and section are intentionally left void to facilitate alignment of the G.992.4 and G.992.3 table of contents.

Annex C

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

The use of G.992.4 over POTS coexisting with TCM-ISDN is under study.

Annex D

ATU-C and ATU-R state diagrams

The ATU-C and ATU-R state diagrams shall be as described in Annex D/G.992.3.

Annex E

POTS and ISDN-BA splitters

G.992.4 is intended for installation primarily without splitters. However, if splitters are provided for operation with POTS they shall be as described in Annex E/G.992.3. The description of splitters for use with ISDN-BA described in Annex E/G.992.3 does not apply.

Annex F

ATU performance requirements for Region A (North America)

The contents of this annex of G.992.4 are for further study.

Annex G

(void annex)

This annex heading and section are intentionally left void to facilitate alignment of the G.992.4 and G.992.3 table of contents.

Annex H

(void annex)

This annex heading and section are intentionally left void to facilitate alignment of the G.992.4 and G.992.3 table of contents.

Annex I

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

This annex defines parameters that have been left unspecified in the body of this Recommendation because they are specific to an ADSL service that is provided without an underlying frequency-division duplexed service.

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

The ATU-C shall support wetting current functionality and related characteristics. The operator may disable the provisioning of wetting current at the ATU-C.

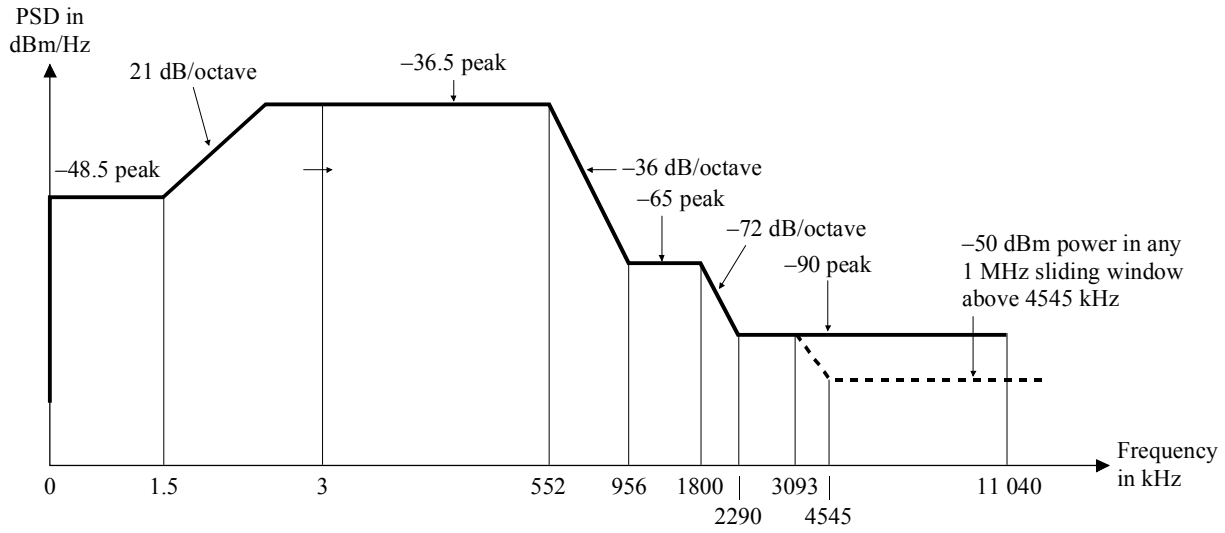
I.1.1 ATU-C control parameter settings

The ATU-C PMD Control Parameter Settings shown in Table A.1 shall be as shown in that table in accordance with the definitions in clause 8. All the values except NSCds may be changed relative to the shown value during G.994.1 as described in clause 8.

I.1.2 ATU-C downstream transmit spectral mask for overlapped spectrum operation

The passband is defined differently from Annex I/G.992.3 as the band from 3 to 552 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 spectral mask for the transmit signal. The low-frequency stop-band is defined as frequencies below 3 kHz, the high-frequency stop-band is defined as frequencies greater than 552 kHz.



Frequency band *f* (kHz)	Equation for line (dBm/Hz)
$0 < f < 1.5$	–48.5
$1.5 < f < 3$	$-36.5 + 12 \times \log_2 (f/3)$
$3 < f < 552$	–36.5
552-956	$-36.5 - 36 \times \log(f/552)/\log(2)$
956-1800	–65
1800-2290	$-65 - 72 \times \log(f/1800)/\log(2)$
2290-3093	–90
$3093 < f < 4545$	–90 peak, with max power in the [*f*,*f* + 1 MHz] window of $(-36.5 - 36 \times \log_2(f/1104) + 60)$ dBm
$4545 < f < 11\,040$	–90 peak, with max power in the [*f*,*f* + 1 MHz] window of –50 dBm

NOTE 1 – All PSD measurements are in 100 Ω.
NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate.
NOTE 3 – Above 3 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth. Below 3 kHz, the peak PSD shall be measured with a 100 Hz resolution bandwidth.
NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.
NOTE 5 – All PSD and power measurements shall be made at the U-C interface.

G.992.4_FI-1

Figure I.1/G.992.4 – ATU-C transmitter PSD mask for overlapped spectrum operation

NOTE – When deployed in the same cable as ADSL-over-POTS (Annex A/G.992.1 and G.992.2 Annexes A & B), 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).

I.1.2.1 Passband PSD and response

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 PSD template nominal passband transmit PSD level is –40 dBm/Hz.

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 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 implementation tolerances and shall not exceed 17.7 dBm;
- the aggregate transmit power over the 0 to 11.04 MHz band shall not exceed (MAXNOMATPds – PCBds) by more than 0.9 dB, in order to account for residual transmit power in the stop bands and implementation tolerances.

For spectrum management purposes, the PSD template nominal passband aggregate transmit power is 17.2 dBm.

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

I.1.3 ATU-C downstream transmit spectral mask for non-overlapped spectrum operation

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 A.1.3, with following modification:

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

I.1.3.1 Passband PSD and response

See A.1.2.1.

I.1.3.2 Aggregate transmit power

See A.1.3.2.

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

The ATU-R PMD control parameter settings, ATU-R downstream transmit spectrum masks, ATU-R passband PSD and response, and ATU-R transmit aggregate transmit power shall conform to I.2/G.992.3.

I.3 Intentionally left blank

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I.4 Electrical characteristics

The requirements for ATU-R POTS current and voltage specifications, electrical characteristics of the ATU-R and ATU-C while in the active state, as defined in I.4/G.992.3, shall be satisfied. The impedance and passband requirements for this clause shall apply across the entire passband as defined for G.992.3 in Annex I (i.e., not only to the passband defined for this Recommendation).

Annex J

(void annex)

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Annex K

TPS-TC functional descriptions

The various TPS-TC types that may be used within the G.992.4 transceivers are described in Annex K/G.992.3. If a TPS-TC type is provided, it shall be implemented as described in Annex K/G.992.3 except as modified by clause 6 of this Recommendation.

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