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**Annex C**  
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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,  
DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Access networks

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

**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**

Recommendation ITU-T G.992.5/Annex C



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
<b>Access networks</b>	<b>G.990–G.999</b>
MULTIMEDIA 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)**

#### **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**

Annex C to Recommendation ITU-T G.992.5 defines those parameters of the ADSL system that have been left undefined in the body of this Recommendation because they are unique to an ADSL service that coexists in the same binder as TCM-ISDN as defined in Appendix III of Recommendation ITU-T G.961. The modifications described in this annex allow a performance improvement from the ADSL system specified in Annex C.Aa in an environment where ADSL and TCM-ISDN operate in the same cable.

This annex has been published independently due to its size and its specific structure.

#### **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.



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## CONTENTS

	<b>Page</b>
C.1 Scope .....	1
C.2 References.....	1
C.3 Definitions .....	1
C.4 Abbreviations and acronyms .....	1
C.5 Reference models.....	1
C.6 Transport protocol-specific transmission convergence (TPS-TC) function.....	1
C.7 Physical media-specific transmission convergence (PMS-TC) function .....	1
C.7.1 Transport capabilities .....	2
C.7.2 Additional functions .....	2
C.7.3 Block interface signals and primitives .....	2
C.7.4 Block diagram and internal reference point signals .....	2
C.7.5 Control parameters .....	2
C.7.6 Frame structure.....	2
C.7.7 Data plane procedures .....	3
C.7.8 Control plane procedures.....	3
C.7.9 Management plane procedures .....	3
C.7.10 Initialization procedures .....	3
C.7.11 On-line reconfiguration .....	5
C.7.12 Power management mode.....	5
C.8 Physical media-dependent function.....	5
C.8.1 Transport capabilities .....	5
C.8.2 Additional functions .....	5
C.8.3 Block interface signals and primitives .....	5
C.8.4 Block diagram and internal reference point signals .....	5
C.8.5 Control parameters .....	5
... 12	
C.8.6 Constellation encoder for data symbols .....	12
C.8.7 Constellation encoder for synchronization and L2 exit symbols .....	12
C.8.8 Modulation .....	12
C.8.9 Transmitter dynamic range.....	14
C.8.10 Transmitter spectral masks .....	14
C.8.11 Control plane procedures.....	14
C.8.12 Management plane procedures .....	14
C.8.13 Initialization procedures .....	14
C.8.14 Short initialization procedures.....	22
C.8.15 Loop diagnostics mode procedures .....	22
C.8.16 On-line reconfiguration of the PMD function.....	30

	<b>Page</b>
C.8.17 Power management in the PMD function .....	30
C.9 Management protocol-specific transmission convergence (MPS-TC) functions.....	30
C.9.1 Transport functions.....	30
C.9.2 Additional functions .....	30
C.9.3 Block interface signals and primitives .....	31
C.9.4 Management plane procedures .....	31
C.10 Dynamic behaviour.....	34
Sub-annex C.Aa – Specific requirements for an Annex C-based ADSL system operating with a downstream bandwidth of 2208 kHz and an upstream bandwidth of 138 kHz.....	35
C.Aa.1 ATU-C functional characteristics (pertains to clause C.8).....	35
C.Aa.2 ATU-R functional characteristics (pertains to Clause C.8).....	40
C.Aa.3 Initialization.....	44
Sub-annex C.Ab – Specific requirements for an Annex C-based ADSL system operating with a downstream bandwidth of 2208 kHz and an upstream bandwidth of 276 kHz.....	45
C.Ab.1 ATU-C functional characteristics (pertains to clause C.8).....	45
C.Ab.2 ATU-R functional characteristics (pertains to clause C.8).....	50
C.Ab.3 Initialization.....	53
Annex C.K – TPS-TC functional descriptions specific to an Annex C-based system .....	54
Appendix C.IV – Example overlapped PSD masks for use in a TCM-ISDN crosstalk environment.....	55



## **Recommendation ITU-T G.992.5**

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

#### **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**

##### **C.1 Scope**

*See clause C.1 of ITU-T G.992.3.*

##### **C.2 References**

*See clause C.2 of ITU-T G.992.3.*

##### **C.3 Definitions**

*See clause C.3 of ITU-T G.992.3.*

##### **C.4 Abbreviations and acronyms**

*See clause C.4 of ITU-T G.992.3.*

##### **C.5 Reference models**

*See clause C.5 of ITU-T G.992.3.*

ITU-T G.992.3 devices fit within the family of DSL Recommendations described in [b-ITU-T G.995.1]. Additionally, ITU-T G.992.3 devices rely upon constituent components described within [ITU-T G.994.1] and [ITU-T G.997.1]. This clause provides the necessary functional, application and protocol reference models so that the subclauses of this Recommendation may be related to these additional Recommendations.

[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.](#)

##### **C.6 Transport protocol-specific transmission convergence (TPS-TC) function**

*See clause C.6 of ITU-T G.992.3.*

##### **C.7 Physical media-specific transmission convergence (PMS-TC) function**

*See clause C.7 of ITU-T G.992.3.*

###### **C.7.1 Transport capabilities**

*See clause C.7.1 of ITU-T G.992.3.*

###### **C.7.2 Additional functions**

*See clause C.7.2 of ITU-T G.992.3.*

### C.7.3 Block interface signals and primitives

See clause C.7.3 of ITU-T G.992.3.

### C.7.4 Block diagram and internal reference point signals

See clause C.7.4 of ITU-T G.992.3.

### C.7.5 Control parameters

See clause C.7.5 of ITU-T G.992.3.

### C.7.6 Frame structure

See clause C.7.6 of ITU-T G.992.3.

#### C.7.6.1 Derived definitions

See clause C.7.6.1 of ITU-T G.992.3.

#### C.7.6.2 Valid framing configurations

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

Table C.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 C.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 C.8.8.1.

...

**Table C.7-8 – Valid framing configurations**

Parameter	Capability
...	...
Relationship of $N_{FEC0}$ and $D_0$	For the downstream latency path #0, configurations that satisfy the following relationship are valid: $(N_{FEC0} - 1) \times (D_0 - 1) \leq 254 \times 63 = 16002$ <del>16002</del> <u>24000</u> For the upstream latency path #0, configurations that satisfy the following relationship are valid: $(N_{FEC0} - 1) \times (D_0 - 1) \leq 254 \times 7 = 1778$
...	...
Relation of $S_p$ and $M_p$	Configurations that satisfy the following relationship are valid: $M_p / 23 \leq S_p \leq 32 \times M_p$ (see Note 1). For the downstream latency path #0, additional valid configurations are: $M_0 / 16 \leq S_0 \leq M_0 / 23$
...	...
Delay constraints	Configurations that satisfy the following relationship are valid: <del>1/2</del> <u>1/3</u> $\leq S_p \leq 64$ (see Note 3) For the downstream latency path #0, additional valid $S_0$ values are: $1/16 \leq S_0 < 1/2 1/3 $
...	...

**Table C.7-8 – Valid framing configurations**

Parameter	Capability
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 C.7-14) and an overhead channel period of 160 ms.	
NOTE 3 – This condition puts bounds on the number of FEC codewords per symbol.	
<del>NOTE 4 – Setting <math>MSG_{min}</math> higher than 28 kbit/s may cause configuration errors and reduce the maximal achievable net data rate.</del>	

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.

### C.7.6.3 Mandatory configurations

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

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

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

### C.7.7 Data plane procedures

See clause C.7.7 of ITU-T G.992.3.

### C.7.8 Control plane procedures

See clause C.7.8 of ITU-T G.992.3.

### C.7.9 Management plane procedures

See clause C.7.9 of ITU-T G.992.3.

### C.7.10 Initialization procedures

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

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

...	...
<b>Spar(2) bit</b>	<b>Definition of related Npar(3) octets</b>
...	...

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

<p>Downstream PMS-TC latency path #0 supported (always set to 1)</p>	<p>Parameter block of 6 octets that describes the maximum net_max downstream rate, downstream <math>S_0</math> min, <del>and</del> downstream <math>D_0</math> <u>and the downstream relationship of <math>N_{FEC0}</math> and <math>D_0</math></u> values supported in the latency path #0. The unsigned 12-bit net_max value is the data rate divided by <del>4000</del><u>8000</u>. 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.</p> <p>The supported range of <math>S_0</math> values shall be indicated by its lower bound <math>S_0</math> min. <math>S_0</math> min shall equal <math>1/(n+1)</math>, with n coded as an unsigned 4-bit value in the 1 to 15 range.</p> <p>The <math>D_0</math> values supported shall be individually indicated with 1 bit per value.</p> <p><u>The "24000 bytes interleaver size" bit indicates the support of different relationships of <math>N_{FEC0}</math> and <math>D_0</math>. If set to ZERO, the ATU shall support all configurations of supported <math>N_{FEC0}</math> and <math>D_0</math> such that <math>(N_{FEC0} - 1) \times (D_0 - 1) \leq 16'002</math>. If set to ONE, the ATU shall support all configurations of supported <math>N_{FEC0}</math> and <math>D_0</math> such that <math>(N_{FEC0} - 1) \times (D_0 - 1) \leq 24'000</math>.</u></p>
<p>Upstream PMS-TC latency path #0 supported (always set to 1)</p>	<p>Parameter block of 3 octets that describes the maximum net_max upstream rate and downstream <math>D_0</math> values supported in the latency path #0. The unsigned 12-bit net_max value is the data rate divided by <del>4000</del><u>8000</u>. 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.</p> <p>The <math>D_0</math> values supported shall be individually indicated with 1 bit per value.</p>
<p>Downstream PMS-TC latency path #1 supported</p>	<p>Parameter block of 4 octets that describes the maximum net_max downstream rate, downstream <math>R_{1\ max}</math>, and downstream <math>D_{1\ max}</math> supported in the latency path #1. The unsigned 12-bit net_max value is the data rate divided by <del>4000</del><u>8000</u>. <math>R_{1\ max}</math> is an unsigned 4-bit value and shall be one of the valid <math>R_p</math> values divided by 2. <math>D_{1\ max}</math> is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid <math>D_p</math> values.</p>
<p>Upstream PMS-TC latency path #1 supported</p>	<p>Parameter block of 4 octets that describes the maximum net_max upstream rate, upstream <math>R_{1\ max}</math>, and upstream <math>D_{1\ max}</math> supported in the latency path #1. The unsigned 12-bit net_max value is the data rate divided by <del>4000</del><u>8000</u>. <math>R_{1\ max}</math> is an unsigned 4-bit value and shall be one of the valid <math>R_p</math> values divided by 2. <math>D_{1\ max}</math> is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid <math>D_p</math> values.</p>
<p>Downstream PMS-TC latency path #2 supported</p>	<p>Parameter block of 4 octets that describes the maximum net_max downstream rate, downstream <math>R_{2\ max}</math>, and downstream <math>D_{2\ max}</math> supported in the latency path #2. The unsigned 12-bit net_max value is the data rate divided by <del>4000</del><u>8000</u>. <math>R_{2\ max}</math> is an unsigned 4-bit value and shall be one of the valid <math>R_p</math> values divided by 2. <math>D_{2\ max}</math> is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid <math>D_p</math> values.</p>
<p>Upstream PMS-TC latency path #2 supported</p>	<p>Parameter block of 4 octets that describes the maximum net_max upstream rate, upstream <math>R_{2\ max}</math>, and upstream <math>D_{2\ max}</math> supported in the latency path #2. The unsigned 12-bit net_max value is the data rate divided by <del>4000</del><u>8000</u>. <math>R_{2\ max}</math> is an unsigned 4-bit value and shall be one of the valid <math>R_p</math> values divided by 2. <math>D_{2\ max}</math> is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid <math>D_p</math> values.</p>
<p>Downstream PMS-TC latency path #3 supported</p>	<p>Parameter block of 4 octets that describes the maximum net_max downstream rate, downstream <math>R_{3\ max}</math>, and downstream <math>D_{3\ max}</math> supported in the latency path #3. The unsigned 12-bit net_max value is the data rate divided by <del>4000</del><u>8000</u>. <math>R_{3\ max}</math> is an unsigned 4-bit value and shall be one of the valid <math>R_p</math> values divided by 2. <math>D_{3\ max}</math> is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid <math>D_p</math> values.</p>
<p>Upstream PMS-TC latency path #3 supported</p>	<p>Parameter block of 4 octets that describes the maximum net_max upstream rate, upstream <math>R_{3\ max}</math>, and upstream <math>D_{3\ max}</math> supported in the latency path #3. The unsigned 12-bit net_max value is the data rate divided by <del>4000</del><u>8000</u>. <math>R_{3\ max}</math> is an unsigned 4-bit value and shall be one of the value <math>R_p</math> values divided by 2. <math>D_{3\ max}</math> is an unsigned 3-bit value and shall be the logarithm base 2 of one of the valid <math>D_p</math> values.</p>

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

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  $\pm 2^{1/3}$  (i.e.,  $n \geq \pm 2$ ). If the  $S_{0\ min}$  octet (see Table C.7-18c) is not included in the CL or CLR message, the  $S_{0\ min}$  value shall be set equal to  $\pm 2^{1/3}$  (implicit indication). The  $S_0$  value selected during the exchange phase (see Table C.7-7 and clause C.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.

...

### **C.7.11 On-line reconfiguration**

*See clause C.7.11 of ITU-T G.992.3.*

### **C.7.12 Power management mode**

*See clause C.7.12 of ITU-T G.992.3.*

## **C.8 Physical media-dependent function**

*See clause C.8 of ITU-T G.992.3.*

### **C.8.1 Transport capabilities**

*See clause C.8.1 of ITU-T G.992.3.*

### **C.8.2 Additional functions**

*See clause C.8.2 of ITU-T G.992.3.*

### **C.8.3 Block interface signals and primitives**

*See clause C.8.3 of ITU-T G.992.3.*

### **C.8.4 Block diagram and internal reference point signals**

*See clause C.8.4 of ITU-T G.992.3.*

### **C.8.5 Control parameters**

#### **C.8.5.1 Definition of control parameters**

*See clause C.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 C.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 C.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 C.8.13.2.4) and to determine the level of spectrum shaping (i.e.,  $tss_j$  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  $[(t_1, PSD_1), (t_2, PSD_2), \dots, (t_N, PSD_N)]$ . The subcarrier index shall be coded as an unsigned integer in the range from  $\text{roundup}(f_{pb\_start}/\Delta f)$  to  $\text{rounddown}(f_{pb\_stop}/\Delta f)$ , where  $f_{pb\_start}$  and  $f_{pb\_stop}$  are the lower and higher edge, of the passband respectively and  $\Delta f$  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:

$$\underline{\underline{MIB\ PSD\ mask(f) = \begin{cases} \text{Limit mask}(f) & f < f_{lm\_start} \\ PSD_1 & f_{lm\_start} \leq f \leq f_1 \\ PSD_N & f_N < f \leq f_{lm\_stop} \\ \text{Limit mask}(f) & f > f_{lm\_stop} \end{cases}}}$$

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 C.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:

$$- t_n < t_{n+1} \text{ for } n = 1 \text{ to } N - 1.$$

$$- f_n = t_n \times \Delta f.$$

2) Low-frequency end and high-frequency end of MIB PSD mask ( $f$ ):

$$- t_1 = \text{roundup}(f_{pb\_start}/\Delta f) \text{ or } (73 \leq t_1 \leq 271).$$

$$- t_N = \text{rounddown}(f_{pb\_stop}/\Delta f).$$

3) MIB PSD stopband in lower frequency part:

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

$$- PSD_1 = -95 \text{ dBm/Hz.}$$

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

- The value  $t_1$  shall be:

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

- 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:

$$MIB \text{ PSD mask}(f) = \begin{cases} PSD_1 + (PSD_2 - PSD_1) \times \frac{\log((f/\Delta f)/t_1)}{\log(t_2/t_1)} & f_1 < f \leq f_2 \end{cases}$$

4) MIB PSD inband shaping:

if  $t_1 = \text{roundup}(f_{pb\_start}/\Delta f)$  then, for  $n = 1$  to  $N - 1$ :

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

- The inband slope shall comply to:

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

-  $\text{MAX}(PSD_n) - \text{MIN}(PSD_n) \leq 20 \text{ dB.}$

-  $\text{MAX PSD of the limit mask} - 20 \text{ dB} \leq \text{MAX}(PSD_n) \leq \text{MAX PSD of the limit mask.}$

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

$$MIB\ PSD\ mask(f) = \begin{cases} PSD_n + (PSD_{n+1} - PSD_n) \times \frac{(f/\Delta f) - t_n}{t_{n+1} - t_n} & f_n < f \leq f_{n+1} \end{cases}$$

NOTE 3 – If the first breakpoint has subcarrier index  $73 \leq t_1 \leq 271$ , then a stopband is created in the lower frequency part of the passband, with spectrum shaping applied to the remainder of the passband. If  $t_1 = \text{roundup}(f_{pb\_start}/\Delta f)$ , 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:

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

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

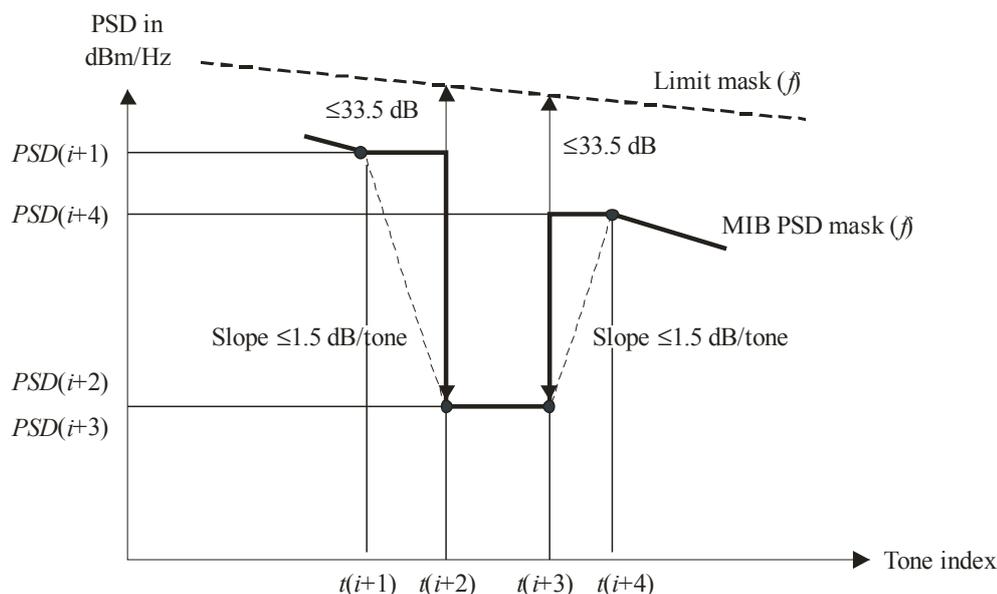
$$PSD_{i+2} = PSD_{i+3}$$

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

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

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

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



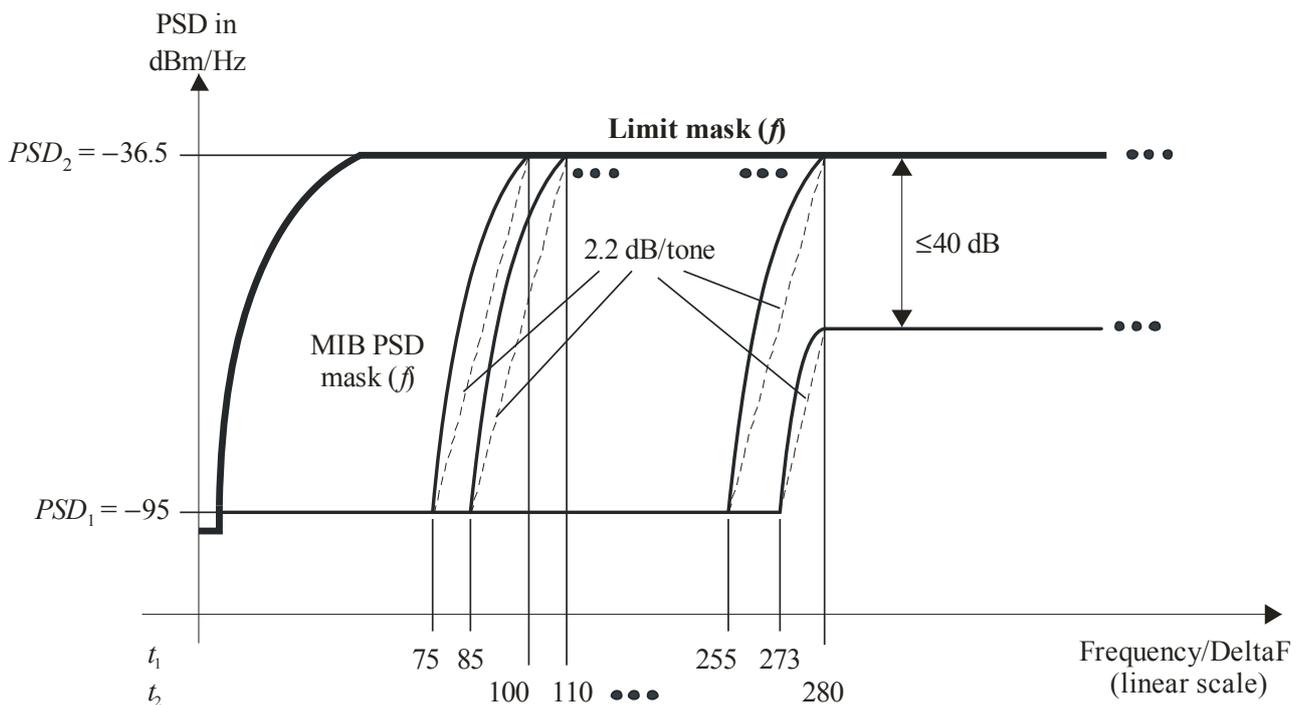
G.992.5(01\_05)\_F8.5.1-1

**Figure C.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  $PSD(i + 2)$ .

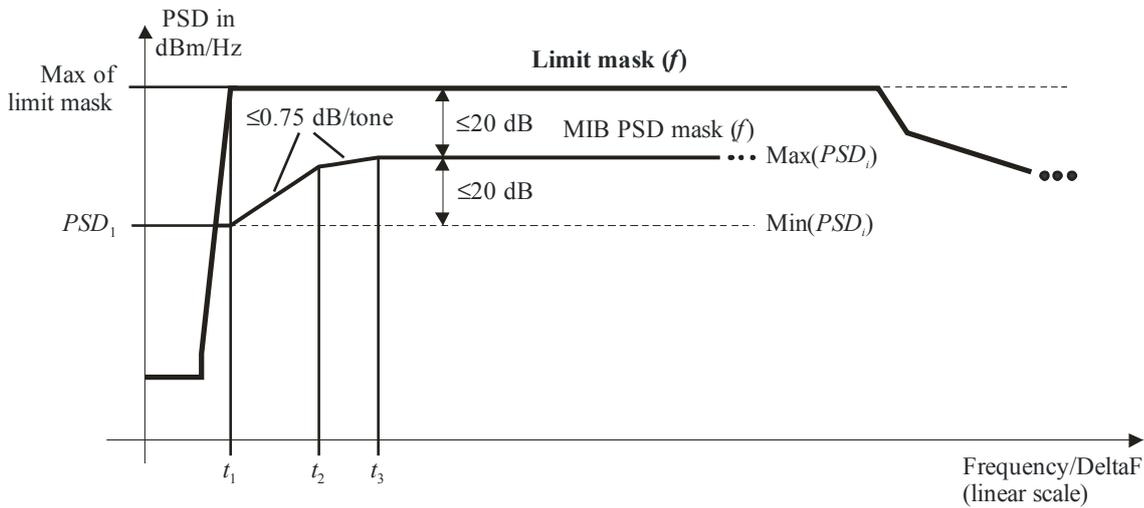
The PSD mask to which the ATU-C transmitter shall comply at the U-C2 reference point shall be the minimum (at each frequency) of the limit PSD mask (specified in Annexes A, B or I) and the CO-MIB PSD mask specified through the CO-MIB.

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.



G.992.5(01\_05)\_F8.5.1-2

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



G.992.5(01\_05)\_F8.5.1-3

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

### C.8.5.2 Mandatory and optional settings of control parameters

See clause C.8.5.2 of ITU-T G.992.3.

### C.8.5.3 Setting control parameters during initialization

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

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

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

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-MEDLEY<sub>us</sub>* indicates the minimum length of the R-MEDLEY state) and the ATU-R (*CA-MEDLEY<sub>ds</sub>* indicates the minimum length of the C-MEDLEY state). See clauses C.8.13.5.1.4 and C.8.13.5.2.4.

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

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

Octet Nr [i]	Parameter	PMD format bits [ $8 \times i + 7$ to $8 \times i + 0$ ]
...	...	...
19	Reserved	[ 0000 0000 ]
<u>20</u>	<u><i>w</i>(0) (LSB)</u>	<u>[ xxxx xxxx ], bit 7 to 0</u>
<u>21</u>	<u><i>w</i>(0) (MSB)</u>	<u>[ xxxx xxxx ], bit 15 to 8</u>

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

Octet Nr [i]	Parameter	PMD format bits [ $8 \times i + 7$ to $8 \times i + 0$ ]
...	...	...
$\frac{18 + NSCds}{32}$	$w(NSCds/64 - 1)$ (LSB)	[ xxxx xxxx ], bit 7 to 0
$\frac{19 + NSCds}{32}$	$w(NSCds/64 - 1)$ (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 C.8.5.1) and can only be used within the transmit PSD mask limitations set by the CO-MIB.

### C.8.5.3.3 During the exchange phase

See clause C.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 C.8-14.

**Table C.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 811-bit unsigned integer, representing a subcarrier index <a href="#">in the 1 to <math>NSC - 1</math> range</a> .

...

## C.8.6 Constellation encoder for data symbols

See clause C.8.6 of ITU-T G.992.3.

## C.8.7 Constellation encoder for synchronization and L2 exit symbols

See clause C.8.7 of ITU-T G.992.3.

## C.8.8 Modulation

See clause C.8.8 of ITU-T G.992.3.

### C.8.8.1 Subcarriers

See clause C.8.8.1 of ITU-T G.992.3.

### C.8.8.2 Inverse discrete fourier transform (IDFT)

See clause C.8.8.2 of ITU-T G.992.3.

### C.8.8.3 Cyclic prefix

See clause C.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  $\Delta f = 4.3125$  kHz and an IDFT size of  $2 \times NSC$ , a cyclic prefix of  $(2 \times NSC \times 5/64)$  samples could be used. That is,

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

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

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

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  $2 \times NSC$  samples, to form a block of  $(2 \times NSC \times 17/16)$  samples. Symbols with cyclic prefix are transmitted at a symbol rate of  $4.3125 \times 16/17 \approx 4.059 \text{ kHz}$ .

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  $(2 \times NSC \times 17/16)$  samples, to form a block of  $(2 \times NSC \times 69/64)$  samples. Symbols with cyclic suffix are transmitted at a symbol rate of  $4.3125 \times 16/17 \approx 4.059 \text{ kHz}$ .

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 C.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.

#### C.8.8.4 Parallel/serial convertor

See clause C.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 C.8-5):

$$\begin{aligned} y_n &= x_n + (2 \times NSC - NSC/8) && \text{for } n = 0 \text{ to } NSC/8 - 1 \\ y_n &= x_n - (NSC/8) && \text{for } n = NSC/8 \text{ to } (17/16) \times 2 \times NSC - 1 \end{aligned}$$

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:

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

where the  $prev\_x(i)$  corresponds to the cyclic suffix of the previous symbol (see clause C.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:

$$\begin{array}{ll}
 w_i \text{ is vendor discretionary} & \text{for } i=0 \text{ to } \frac{NSC}{64}-1 \\
 w_i = 1 - w\left(\frac{NSC}{32}-1-i\right) & \text{for } i = \frac{NSC}{64} \text{ to } \frac{NSC}{32}-1 \\
 w_i = 1 & \text{for } i = \frac{NSC}{32} \text{ to } 2 \times NSC \times \frac{17}{16}-1 \\
 w_i = w\left(2 \times NSC \times \frac{69}{64}-1-i\right) & \text{for } i = 2 \times NSC \times \frac{17}{16} \text{ to } 2 \times NSC \times \frac{69}{64}-1
 \end{array}$$

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:

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

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 C.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 C.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 C.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.

### **C.8.8.5 DAC and AFE**

*See clause C.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 C.5.4). The analogue front end may include filtering.

### **C.8.9 Transmitter dynamic range**

*See clause C.X of ITU-T G.992.3, adding the following text immediately before clause C.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.

## C.8.10 Transmitter spectral masks

See clause C.8.10 of ITU-T G.992.3.

## C.8.11 Control plane procedures

See clause C.8.11 of ITU-T G.992.3.

## C.8.12 Management plane procedures

See clause C.8.12 of ITU-T G.992.3.

## C.8.13 Initialization procedures

### C.8.13.1 Overview

See clause C.8.13.1 of ITU-T G.992.3.

### C.8.13.2 ITU-T G.994.1 phase

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

[The ITU-T G.992.5 handshake codepoints are defined in \[ITU-T G.994.1\].](#)

#### C.8.13.2.1 Handshake – ATU-C

See clause C.8.13.2.1 of ITU-T G.992.3.

##### C.8.13.2.1.1 CL messages

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

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

<a href="#">Npar(2)</a>	<a href="#">Definition for CL message</a>
<a href="#">Downstream spectrum shaping using time domain filtering only</a>	<a href="#">When set to 1, the ATU-C indicates that only time domain filtering is used to shape the downstream inband spectrum.</a>

[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.](#)

#### C.8.13.2.2 Handshake – ATU-R

See clause C.8.13.2.2 of ITU-T G.992.3.

##### C.8.13.2.2.1 CLR messages

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

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

<u>Npar(2)</u>	<u>Definition for CLR message</u>
<u>Downstream spectrum shaping using time domain filtering only</u>	<u>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.</u>

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.

### **C.8.13.2.3 ITU-T G.994.1 transmit PSD levels**

*See clause C.8.13.2.3 of ITU-T G.992.3.*

### **C.8.13.2.4 Spectral bounds and shaping parameters**

*See clause C.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 C.8-1 is the Fourier transform of the autocorrelation function of the window  $w(t)$  (see clause C.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:

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

- The  $\text{ceiled\_log\_}tss_i$  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 C.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.

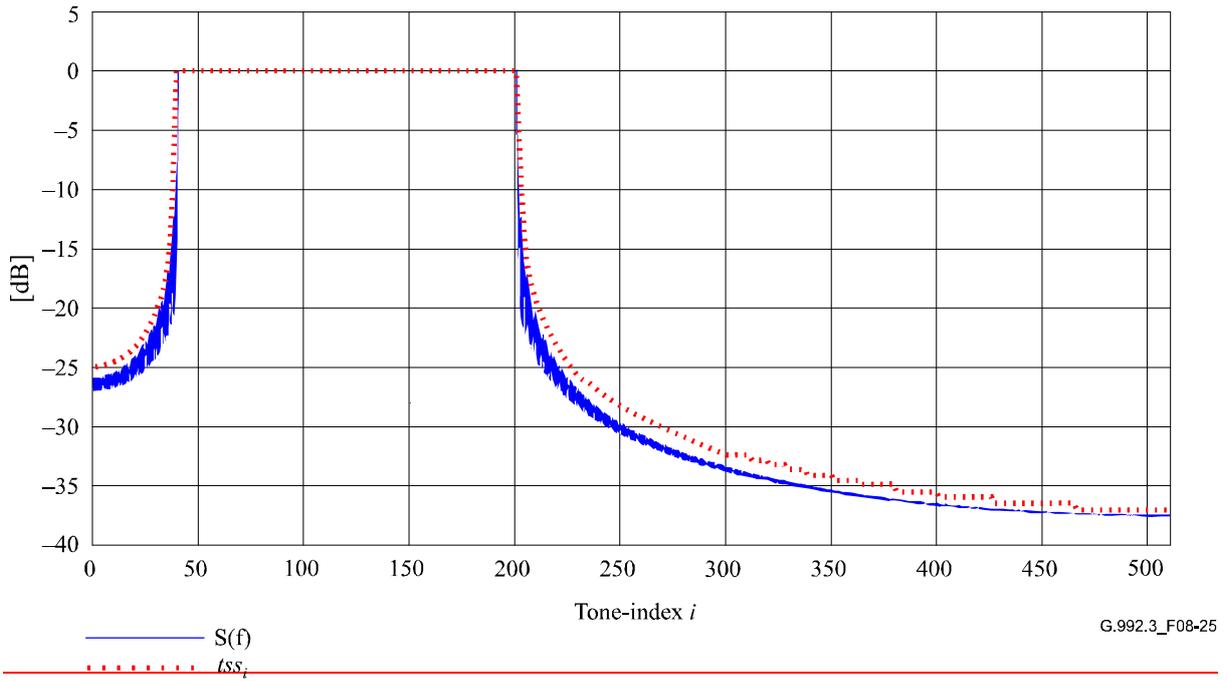
NOTE 5 – This corresponds to a ceiling of the transmit PSD to the REFPSDds level over the subcarriers included in the SUPPORTEDset, and a lowering of the transmit PSD by PCBds dB over the subcarriers not included in the SUPPORTEDset. Depending on the spectrum shaping applied through the  $tss_i$  values 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.

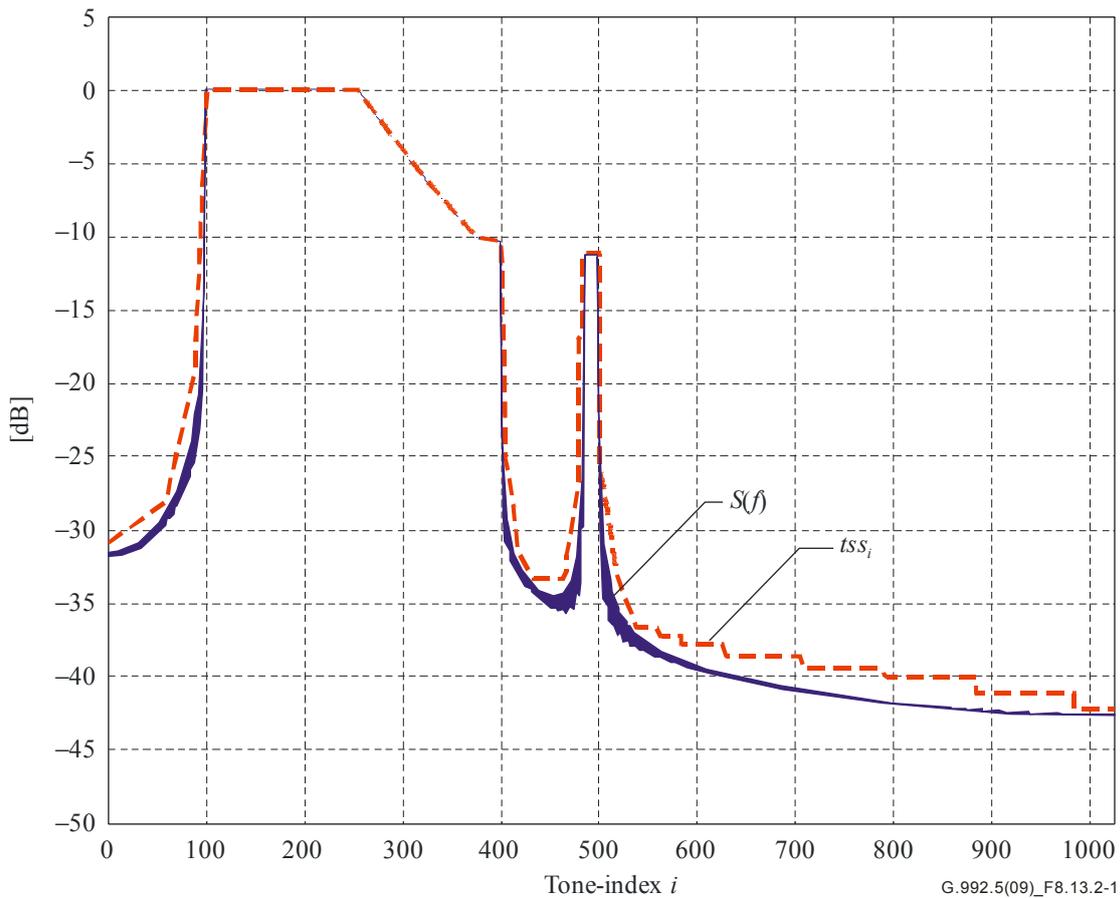
Figure C.8-25 shows an example of the downstream  $tss_i$  values as a function of the subcarrier index  $i$ , for the case that the SUPPORTEDset contains the subcarriers with index  ~~$i = 40$  to  $200$~~  and  ~~$N = 2 \times \text{NSC} = 512$~~   $i = 100$  to  $399$  and  $i = 484$  to  $500$  and for  $N = 2 \times \text{NSC} = 1024$  (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.

Transmit spectrum shaping values and downstream spectrum  $S(f)$  [40, 200]



Transmit spectrum shaping values and spectrum  $S(f)$  [100, 500] with HAM-band 1.8-2 MHz (no windowing)



**Figure C.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 the subcarrier is or is not 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.

...

### **C.8.13.3 Channel discovery phase**

*See clause C.8.13.3 of ITU-T G.992.3.*

#### **C.8.13.3.1 ATU-C channel discovery**

*See clause C.8.13.3.1 of ITU-T G.992.3.*

##### **C.8.13.3.1.1 C-QUIET1**

*See clause C.8.13.3.1.1 of ITU-T G.992.3.*

##### **C.8.13.3.1.2 C-TTRSYNC1**

*See clause C.8.13.3.1.2 of ITU-T G.992.3.*

##### **C.8.13.3.1.3 C-QUIET-TTR1**

*See clause C.8.13.3.1.3 of ITU-T G.992.3.*

##### **C.8.13.3.1.4 C-COMB2**

*See clause C.8.13.3.1.4 of ITU-T G.992.3.*

##### **C.8.13.3.1.5 C-ICOMB1**

*See clause C.8.13.3.1.5 of ITU-T G.992.3.*

##### **C.8.13.3.1.6 C-LINEPROBE**

*See clause C.8.13.3.1.6 of ITU-T G.992.3.*

##### **C.8.13.3.1.7 C-QUIET-TTR2**

*See clause C.8.13.3.1.7 of ITU-T G.992.3.*

##### **C.8.13.3.1.8 C-COMB3**

*See clause C.8.13.3.1.8 of ITU-T G.992.3.*

### C.8.13.3.1.9 C-ICOMB2

See clause C.8.13.3.1.9 of ITU-T G.992.3.

### C.8.13.3.1.10 C-MSG-FMT

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

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

Bit index	Parameter	Definition
0	<i>FMT_R-REVERB1</i> (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	<i>FMT_C-REVERB4</i> (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	<i>FMT_R-QUIET4</i> (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	<i>FMT_C-MSG-PCB</i>	Set to 1 indicates that the C-MSG-PCB message shall include the C-BLACKOUT bits. Set to 0 indicates it shall not.
<u>9</u>	<u><i>FMT_C-MSG1</i></u>	<u>Set to 1 indicates that windowing is applied with window samples included in the C-MSG1 message.</u> <u>Set to 0 indicates no windowing is applied and no window samples are included in C-MSG1 message.</u>
<u>10</u>	<u><i>FMT-C-MEDLEYPRBS</i></u>	<u>Set to 1 indicates that the ATU-C requests to use the higher order PRBS for the C-MEDLEY data pattern (see clause C.8.13.5.1.4).</u>
15.. <del>9</del> <u>11</u>		Reserved, set to 0.

### C.8.13.3.2 ATU-R channel discovery

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

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

Bit index	Parameter	Definition
0	<i>FMT-R-REVERB1</i> (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	<i>FMT-C-REVERB4</i> (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	<i>FMT-C-TREF1</i> (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	<i>FMT-R-MSG-PCB</i> (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	<i>FMT-C-TREF2</i> (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	<i>FMT-C-PILOT</i> (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.
<u>10</u>	<u><i>FMT-C-MEDLEYPRBS</i></u>	<u>Set to 1 indicates that the ATU-R requests to use the higher order PRBS for the C-MEDLEY data pattern (see clause C.8.13.5.1.4).</u>
15.. <del>10</del> <u>11</u>		Reserved, set to 0.

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

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

#### C.8.13.4 Transceiver training phase

See clause C.8.13.4 of ITU-T G.992.3.

#### C.8.13.5 Channel analysis phase

See clause C.8.13.5 of ITU-T G.992.3.

##### C.8.13.5.1 ATU-C channel analysis

See clause C.8.13.5.1 of ITU-T G.992.3.

### C.8.13.5.1.1 C-MSG1

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

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

Part of message	Length (bits or symbols)
Prefix	32
$N_{pmd}$ (see Note)	160 <u>or</u> $160 + NSCds/4$
$N_{pms}$	32
$N_{tps}$	0
$N_{msg}$	192 <u>or</u> $192 + NSCds/4$
CRC	16
$LEN\_C-MSG1$ (symbols)	240 <u>or</u> $240 + NSCds/4$
<u>NOTE – Length depends on whether or not windowing is applied (see clause 8.5.3.2).</u>	

### C.8.13.5.1.2 C-REVERB5

See clause C.8.13.5.1.2 of ITU-T G.992.3.

### C.8.13.5.1.3 C-SEGUE2

See clause C.8.13.5.1.3 of ITU-T G.992.3.

### C.8.13.5.1.4 C-MEDLEY

See clause C.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 during both  $FEXT_R$  and  $NEXT_R$  symbols when Bitmap- $N_R$  is enabled (DBM). When Bitmap- $N_R$  is disabled (FBM), the ATU-C shall transmit C-MEDLEY symbols only during  $FEXT_R$  symbols and the C-TREF pilot tone during  $NEXT_R$  symbols, except for profile 3 where C-QUIET is transmitted during  $NEXT_R$  symbols. In the C-MEDLEY state, the ATU-C shall transmit  $LEN\_MEDLEY$  symbols. The value  $LEN\_MEDLEY$  shall be the maximum of the  $CA-MEDLEY_{us}$  and  $\bar{C}A-MEDLEY_{ds}$  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  $3 \times 345$  and shall be less than or equal to 65205. 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:

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

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 14<sup>th</sup> 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  $d_{512 \times (i+1)}$~~   $2 \times NSCds$  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 (~~5122~~ $\times NSCds$  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 C.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.

### C.8.13.6 Exchange phase

See clause C.8.13.6 of ITU-T G.992.3.

### C.8.14 Short initialization procedures

See clause C.8.14 of ITU-T G.992.3.

### C.8.15 Loop diagnostics mode procedures

See clause C.8.15 of ITU-T G.992.3.

#### C.8.15.1 Overview

See clause C.8.15.1 of ITU-T G.992.3.

#### C.8.15.2 Channel discovery phase

##### C.8.15.2.1 ATU-C channel discovery phase

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

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

Bit index	Parameter	Definition
<u>9..0</u>		<u>Reserved, set to 0</u>
<u>10</u>	<u>FMT-C-MEDLEYPRBS</u>	<u>See Table 8-26</u>
15 .. <del>0</del> <u>11</u>		Reserved, set to 0

##### C.8.15.2.2 ATU-R channel discovery phase

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

**Table C.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 C.8-31
9	FMT-C-PILOT	See Table C.8-31
<u>10</u>	<u>FMT-C-MEDLEYPRBS</u>	<u>See Table C.8-31</u>
15... <del>4</del> <u>11</u>		Reserved, set to 0

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

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

### C.8.15.3 Transceiver training phase

See clause C.8.15.3 of ITU-T G.992.3.

### C.8.15.4 Channel analysis phase

See clause C.8.15.4 of ITU-T G.992.3.

### C.8.15.5 Exchange phase

See clause C.8.15.5 of ITU-T G.992.3.

#### C.8.15.5.1 ATU-C exchange phase

See clause C.8.15.5.1 of ITU-T G.992.3.

#### C.8.15.5.2 ATU-R exchange phase

See clause C.8.15.5.2 of ITU-T G.992.3.

##### C.8.15.5.2.1 Channel information bearing messages

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

In the loop diagnostics mode, the ATU-R shall send ~~eleven~~  $(1 + \text{NSCds}/32)$  messages to the ~~R-MSG1-LD to R-MSG11-LD~~ R-MSGx-LD, numbered from  $x = 1$  to  $1 + \text{NSCds}/32$ . These messages contain the downstream test parameters defined in clause C.8.15.1.

The information fields of the different messages shall be as shown in Tables C.8-55 to C.8-63, C.8.15-3 and C.8.15-4.

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

<b>Octet Nr [i]</b>	<b>Information</b>	<b>Format message bits [8 × i + 7 to 8 × i + 0]</b>
0	Sequence number	[ <del>0001</del> 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	<i>LATN</i> (LSB)	[ xxxx xxxx ], bit 7 to 0
5	<i>LATN</i> (MSB)	[ 0000 00xx ], bit 9 and 8
6	<i>SATN</i> (LSB)	[ xxxx xxxx ], bit 7 to 0
7	<i>SATN</i> (MSB)	[ 0000 00xx ], bit 9 and 8
8	FEXT <i>SNRM</i> (LSB)	[ xxxx xxxx ], bit 7 to 0
9	FEXT <i>SNRM</i> (MSB)	[ 0000 00xx ], bit 9 and 8
10	FEXT <i>ATTNDR</i> (LSB)	[ xxxx xxxx ], bit 7 to 0
11	FEXT <i>ATTNDR</i>	[ xxxx xxxx ], bit 15 to 8
12	FEXT <i>ATTNDR</i>	[ xxxx xxxx ], bit 23 to 16
13	FEXT <i>ATTNDR</i> (MSB)	[ xxxx xxxx ], bit 31 to 24
14	FEXT far-end <i>ACTATP</i> (LSB)	[ xxxx xxxx ], bit 7 to 0
15	FEXT far-end <i>ACTATP</i> (MSB)	[ ssss sxxx ], bit 9 and 8
16	NEXT <i>SNRM</i> (LSB)	[ xxxx xxxx ], bit 7 to 0
17	NEXT <i>SNRM</i> (MSB)	[ 0000 00xx ], bit 9 and 8
18	NEXT <i>ATTNDR</i> (LSB)	[ xxxx xxxx ], bit 7 to 0
19	NEXT <i>ATTNDR</i>	[ xxxx xxxx ], bit 15 to 8
20	NEXT <i>ATTNDR</i>	[ xxxx xxxx ], bit 23 to 16
21	NEXT <i>ATTNDR</i> (MSB)	[ xxxx xxxx ], bit 31 to 24
22	NEXT far-end <i>ACTATP</i> (LSB)	[ xxxx xxxx ], bit 7 to 0
23	NEXT far-end <i>ACTATP</i> (MSB)	[ ssss sxxx ], bit 9 and 8

**Table C.8-56/57/58/59 – Format of the Hlin(i) R-MSG<sub>2x</sub>-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)
1	Reserved	[ 0000 0000 ]
2	Hlin(64 × k) real (LSB)	[ xxxx xxxx ], bit 7 to 0
3	Hlin(64 × k) real (MSB)	[ xxxx xxxx ], bit 15 to 8
4	Hlin(64 × k) imag (LSB)	[ xxxx xxxx ], bit 7 to 0
5	Hlin(64 × k) imag (MSB)	[ xxxx xxxx ], bit 15 to 8
.....	.....	.....
254	Hlin(64 × k + 63) real (LSB)	[ xxxx xxxx ], bit 7 to 0
255	Hlin(64 × k + 63) real (MSB)	[ xxxx xxxx ], bit 15 to 8
256	Hlin(64 × k + 63) imag (LSB)	[ xxxx xxxx ], bit 7 to 0
257	Hlin(64 × 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-MSG<sub>x</sub>-LD message shall be transmitted, with sequence number  $x = 2 + k$ .

**Table C.8-57 – Format of the R-MSG<sub>3</sub>-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 C.8-58 – Format of the R-MSG<sub>4</sub>-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

Octet Nr [i]	Information	Format message bits $[8 \times i + 7 \text{ to } 8 \times i + 0]$
.....	.....	.....
254	Hlin(191) real (LSB)	[xxxx xxxx], bit 7 to 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 C.8-59—Format of the R-MSG5-LD message**

Octet Nr [i]	Information	Format message bits $[8 \times i + 7 \text{ to } 8 \times i + 0]$
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 C.8-60/61 – Format of the Hlog(i) R-MSG6x-LD message**

Octet Nr [i]	Information	Format message bits $[8 \times i + 7 \text{ to } 8 \times i + 0]$
0	Sequence number	[0110 0110] [xxxx xxxx] (as 8-bit unsigned integer)
1	Reserved	[ 0000 0000 ]
2	Hlog( $\theta \cdot 128 \times k$ ) (LSB)	[ xxxx xxxx ], bit 7 to 0
3	Hlog( $\theta \cdot 128 \times k$ ) (MSB)	[ 0000 00xx ], bit 9 and 8
.....	.....	.....
256	Hlog( $128 \times k + 127$ ) (LSB)	[ xxxx xxxx ], bit 7 to 0
257	Hlog( $128 \times k + 127$ ) (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 C.8-61—Format of the R-MSG7-LD message**

Octet Nr [i]	Information	Format message bits $[8 \times i + 7 \text{ to } 8 \times i + 0]$
0	Sequence number	[0111 0111]

Octet Nr [i]	Information	Format message bits [8 × i + 7 to 8 × i + 0]
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 C.8-62 – Format of the FEXT QLN(i) R-MSG<sub>8x</sub>-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	FEXT QLN( <u>0256 × k</u> )	[ xxxx xxxx ], bit 7 to 0
.....	.....	.....
257	FEXT QLN( <u>256 × k + 255</u> )	[ xxxx xxxx ], bit 7 to 0

NOTE – For each of the values  $k = 0$  to  $NSCds/256 - 1$ , a single R-MSG<sub>x</sub>-LD message shall be transmitted, with sequence number  $x = 3 \times NSCds/128 + 2 + k$ .

Table C.8-63 – Format of the SNR(i) R-MSG<sub>9x</sub>-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	FEXT SNR( <u>0256 × k</u> )	[ xxxx xxxx ], bit 7 to 0
.....	.....	.....
257	FEXT SNR( <u>256 × k + 255</u> )	[ xxxx xxxx ], bit 7 to 0

NOTE – For each of the values  $k = 0$  to  $NSCds/256 - 1$ , a single R-MSG<sub>x</sub>-LD message shall be transmitted, with sequence number  $x = 7 \times NSCds/256 + 2 + k$ .

Table C.8.15-3 – Format of the NEXT QLN(i) R-MSG<sub>10</sub>-LD message

Octet Nr [i]	Information	Format message bits [8 × i + 7 to 8 × i + 0]
0	Sequence number	[ 1010 1010 ] [ xxxx xxxx ] (as 8-bit unsigned integer)
1	Reserved	[ 0000 0000 ]
2	NEXT QLN( <u>0256 × k</u> )	[ xxxx xxxx ], bit 7 to 0
...	...	...
257	NEXT QLN( <u>256 × k + 255</u> )	[ 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  $x = 4 \times NSCds/128 + 2 + k$ .

**Table C.8.15-4 – Format of the NEXT SNR(i) R-MSG11-LD message**

Octet Nr [i]	Information	Format message bits $[8 \times i + 7$ to $8 \times i + 0]$
0	Sequence number	<del>[1011 1011]</del> [ xxxx xxxx ] (as 8-bit unsigned integer)
1	Reserved	[ 0000 0000 ]
2	NEXT SNR( <del>0</del> <u><math>256 \times k</math></u> )	[ xxxx xxxx ], bit 7 to 0
...	...	...
257	NEXT SNR( <u><math>256 \times k + 255</math></u> )	[ 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  $x = 9 \times NSCds/256 + 2 + k$ .

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 C.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 C.8-64.

**Table C.8-64 – ATU-R loop diagnostics state durations**

State	Duration (round up in hyperframes)
R-MSG1-LD	$[24 \times 8 + 16]/34 = 7$
<u>R-MSGx-LD</u> <u>(<math>x = 2</math> to <math>10 \times NSCds/256 + 1</math>)</u>	<u><math>[258 \times 8 + 16]/34 = 62</math></u>
<del>R-MSG2-LD</del>	<del><math>[258 \times 8 + 16]/34 = 62</math></del>
<del>R-MSG3-LD</del>	<del><math>[258 \times 8 + 16]/34 = 62</math></del>
<del>R-MSG4-LD</del>	<del><math>[258 \times 8 + 16]/34 = 62</math></del>
<del>R-MSG5-LD</del>	<del><math>[258 \times 8 + 16]/34 = 62</math></del>
<del>R-MSG6-LD</del>	<del><math>[258 \times 8 + 16]/34 = 62</math></del>
<del>R-MSG7-LD</del>	<del><math>[258 \times 8 + 16]/34 = 62</math></del>
<del>R-MSG8-LD</del>	<del><math>[258 \times 8 + 16]/34 = 62</math></del>
<del>R-MSG9-LD</del>	<del><math>[258 \times 8 + 16]/34 = 62</math></del>
<del>R-MSG10-LD</del>	<del><math>[258 \times 8 + 16]/34 = 62</math></del>
<del>R-MSG11-LD</del>	<del><math>[258 \times 8 + 16]/34 = 62</math></del>

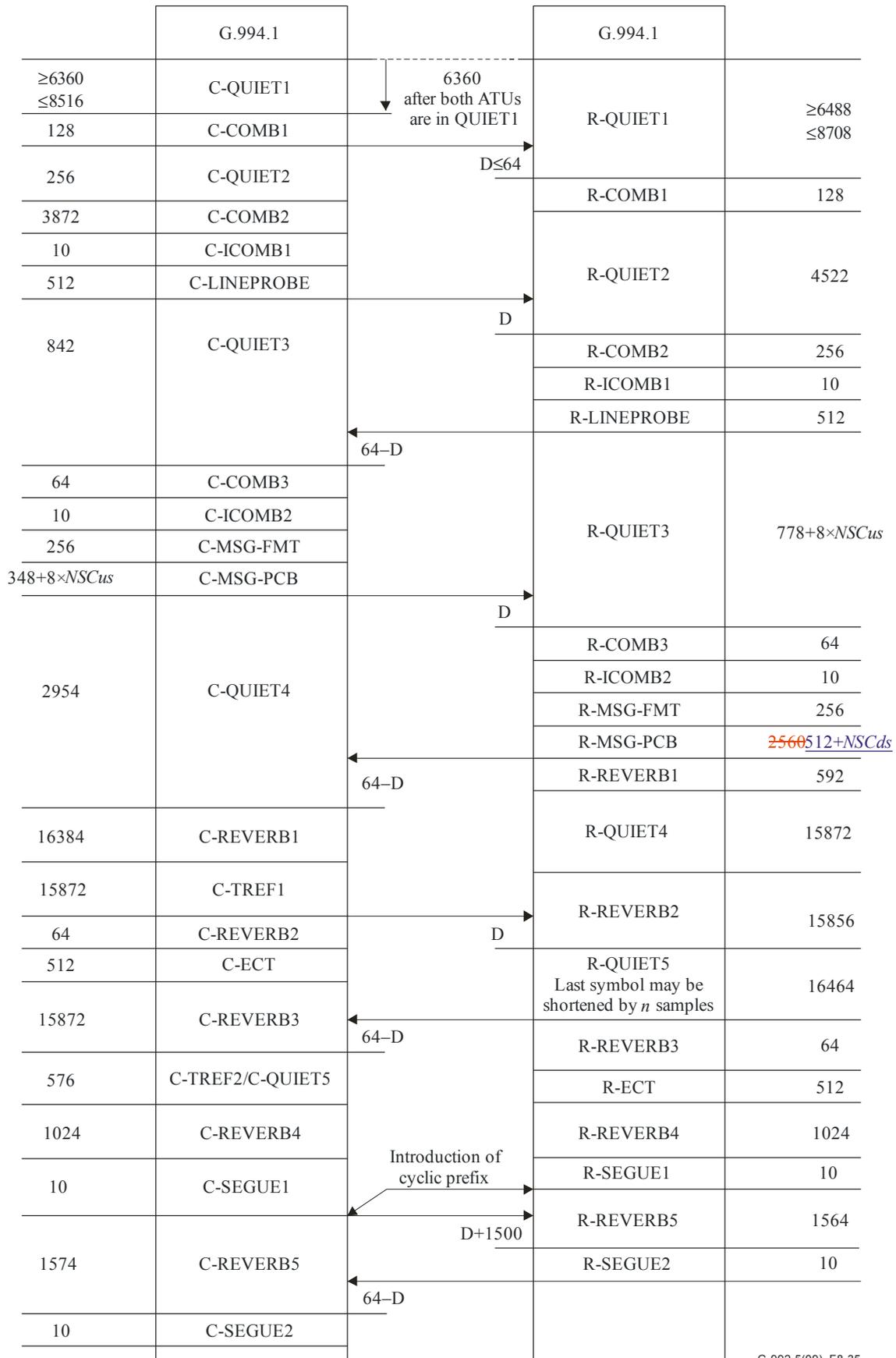
The resulting number of hyperframes needed to transmit each of the messages and CRC is shown in the loop diagnostics timing diagrams in Figures C.8-35 and C.8-36.

#### **C.8.15.5.2.2 Message flow, acknowledgement and retransmission**

See clause C.8.15.5.2.2 of ITU-T G.992.3.

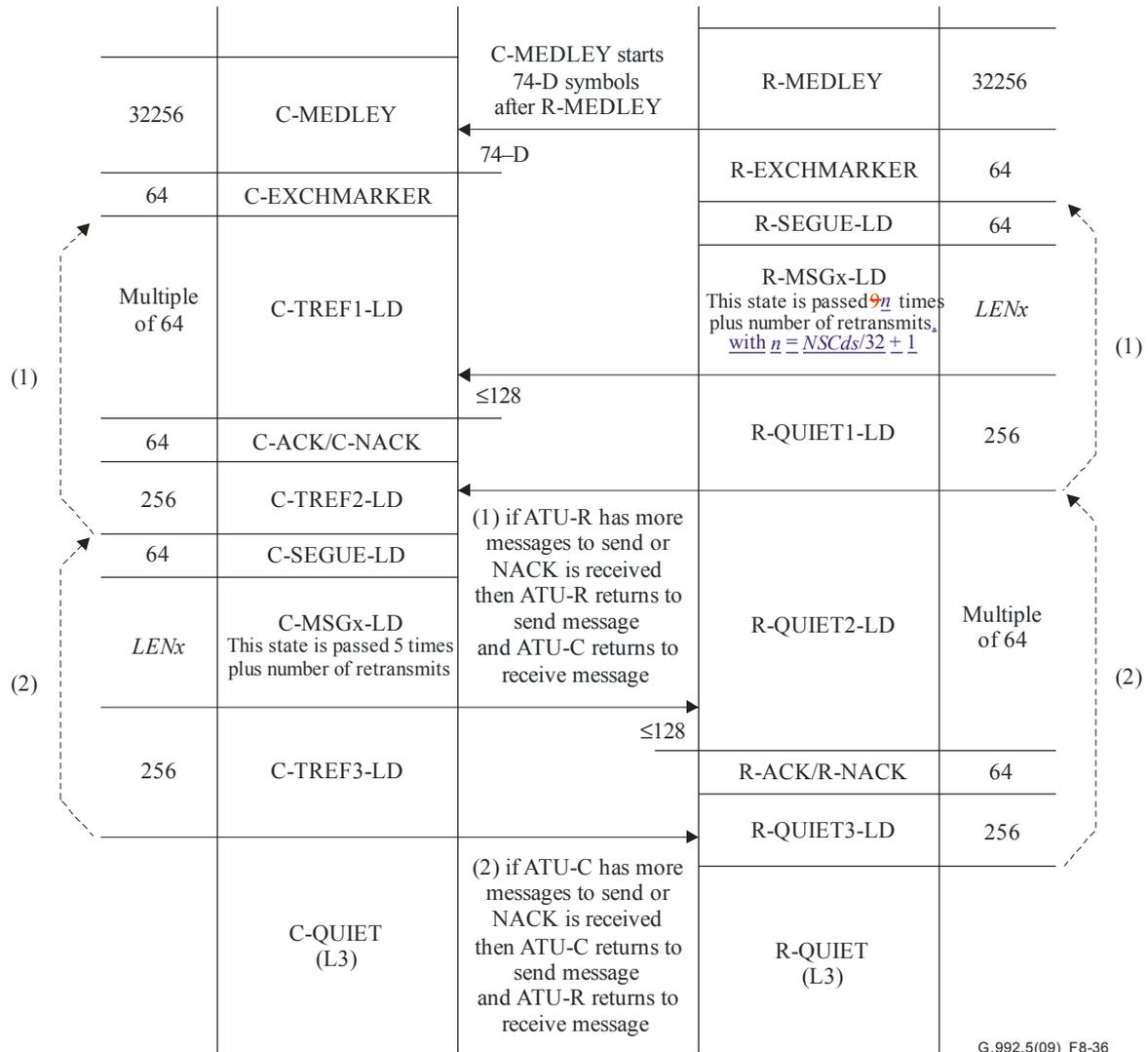
### C.8.15.6 Timing diagram of the loop diagnostics procedures

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



G.992.5(09)\_F8-35

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



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

**C.8.16 On-line reconfiguration of the PMD function**

See clause C.8.16 of ITU-T G.992.3.

**C.8.17 Power management in the PMD function**

See clause C.8.17 of ITU-T G.992.3.

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

See clause C.9 of ITU-T G.992.3.

**C.9.1 Transport functions**

See clause C.9.1 of ITU-T G.992.3.

**C.9.2 Additional functions**

See clause C.9.2 of ITU-T G.992.3.

### **C.9.3 Block interface signals and primitives**

*See clause C.9.3 of ITU-T G.992.3.*

### **C.9.4 Management plane procedures**

#### **C.9.4.1 Commands**

*See clause C.9.4.1 of ITU-T G.992.3.*

##### **C.9.4.1.1 On-line reconfiguration command**

*See clause C.9.4.1.1 of ITU-T G.992.3, modified as follows:*

The on-line reconfiguration commands shall be used to control certain on-line dynamic behaviour defined in this clause. Additional information is provided on this dynamic behaviour in clause C.10. On-line reconfiguration commands may be initiated by either ATU as shown in Table C.9-7. However, the initiator is only provided with means to effect changes in its receiver and the corresponding transmitter. The responding ATU may use the on-line reconfiguration commands shown in Table C.9-8 or may positively acknowledge the initiator's request by transmitting a line signal corresponding to the PMD.Synchflag primitive. The on-line reconfiguration commands shall consist of multiple octets. The first octet shall be the on-line reconfiguration command designator shown in Table C.9-2. The remaining octets shall be as shown in Tables C.9-7, C.9-8 and C.9-9. The octets shall be sent using the format described in clause C.7.8.2.3 and using the protocol described in clause C.7.8.2.4.

On-line reconfiguration commands in this annex are based on clause 9.4.1.1 of the main body of this Recommendation with the following changes:

- Request type 1 (bitswap) messages shall be restricted to only one bitmap per transaction.
- Request type 2 (DRR) message shall be left for further study.
- Request type 3 (SRA) messages shall allow changing *L* parameter for both FEXT and NEXT and shall be restricted to only one bitmap per transaction.

The same message designator (0000 0001b) shall be used for both FEXT and NEXT bitmap OLR commands. The OLR commands are listed in Table C.9-7.

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

Message length (octets)	Element name (command)
$3 + 34 + 4 \times N_f$	01 <sub>16</sub> FEXT bitmap request type 1 followed by: <del>1 octet</del> <u>2 octets</u> for the number of subcarriers $N_f$ $34 \times N_f$ octets describing FEXT bitmap subcarrier parameter field for each subcarrier
$34 + 8 \times N_{LP} + 34 \times N_f$	08 <sub>16</sub> FEXT bitmap request type 3 followed by: $2 \times N_{LP}$ octets containing new $Lf3_P$ values for the $N_{LP}$ -enabled latency paths, $2 \times N_{LP}$ octets containing new $Ln3_P$ values for the $N_{LP}$ -enabled latency paths, $2 \times N_{LP}$ octets containing new $Lf4_P$ values for the $N_{LP}$ -enabled latency paths, $2 \times N_{LP}$ octets containing new $Ln4_P$ values for the $N_{LP}$ -enabled latency paths, <u>2 octets</u> for the number of carriers $N_f$ $34 \times N_f$ octets describing FEXT bitmap subcarrier parameter field for each subcarrier
$34 + 34 \times N_f$	09 <sub>16</sub> NEXT bitmap request type 1 followed by: <u>2 octets</u> for the number of subcarriers $N_f$ $34 \times N_f$ octets describing NEXT bitmap subcarrier parameter field for each subcarrier
$34 + 8 \times N_{LP} + 34 \times N_f$	0A <sub>16</sub> NEXT bitmap request type 3 followed by: $2 \times N_{LP}$ octets containing new $Lf3_P$ values for the $N_{LP}$ -enabled latency paths, $2 \times N_{LP}$ octets containing new $Ln3_P$ values for the $N_{LP}$ -enabled latency paths, $2 \times N_{LP}$ octets containing new $Lf4_P$ values for the $N_{LP}$ -enabled latency paths, $2 \times N_{LP}$ octets containing new $Ln4_P$ values for the $N_{LP}$ -enabled latency paths, <u>2 octets</u> for the number of carriers $N_f$ $34 \times N_f$ octets describing NEXT bitmap subcarrier parameter field for each subcarrier
All other octet values are reserved by ITU-T.	

**Table C.9-8 – On-line reconfiguration commands transmitted by the responding transmitter**

Message length (octets)	Element name (command)
3	81 <sub>16</sub> Defer type 1 request followed by: 1 octet for reason code
3	82 <sub>16</sub> Reject type 2 request followed by: 1 octet for reason code
3	83 <sub>16</sub> Reject type 3 request followed by: 1 octet for reason code
All other octet values are reserved by ITU-T.	

An ATU may request only changes in its receiver operation. Changes may be requested concurrently by both ATUs; each transaction shall follow the procedures described in this clause. An ATU-R shall not initiate an OLR command if it has transmitted an L2 grant command and is awaiting a response.

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.

...

#### **C.9.4.1.2 eoc commands**

*See clause C.9.4.1.2 of ITU-T G.992.3.*

#### **C.9.4.1.3 Time commands**

*See clause C.9.4.1.3 of ITU-T G.992.3.*

#### **C.9.4.1.4 Inventory command**

*See clause C.9.4.1.4 of ITU-T G.992.3.*

#### **C.9.4.1.5 Control value read commands**

*See clause C.9.4.1.5 of ITU-T G.992.3.*

#### **C.9.4.1.6 Management counter read commands**

*See clause C.9.4.1.6 of ITU-T G.992.3.*

#### **C.9.4.1.7 Power management commands**

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

A subcarrier parameter field contains 2 octets formatted as [ cccc cccc 0000 bbbb ], the carrier index  $i$  (8 bits) and the  $b_i$  (4 bits). The carrier index shall be the first octet of the subcarrier field. The  $b_i$  shall be the least significant 4 bits of the second octet.

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<sub>i</sub> values as determined and applied during transceiver training).

#### **C.9.4.1.8 Clear eoc messages**

*See clause C.9.4.1.8 of ITU-T G.992.3.*

#### **C.9.4.1.9 Non-standard facility overhead commands**

*See clause C.9.4.1.9 of ITU-T G.992.3.*

#### **C.9.4.1.10 Test parameter messages**

See clause C.9.4.1.10 of ITU-T G.992.3, modifying the first paragraph and Table C.8-28 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 C.9-28. The responses shall be using the command shown in Table C.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 C.9-4. The remaining octets shall be as shown in Table C.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 C.9-4. ~~The second shall correspond to the received PMD test parameter read command second octet, XOR 80<sub>16</sub>, except for the next multiple read command (see Tables C.9-28 and C.9-29).~~ The remaining octets shall be as shown in Table C.9-29. The octets shall be sent using the format described in clause C.7.8.2.3 and using the protocol described in clause C.7.8.2.4.

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

Message length (octets)	Element name (command)
3	01 <sub>16</sub> Single read followed by: 1 octet describing the test parameter ID
<del>3</del>	<del>02<sub>16</sub> Multiple read block followed by: 1 octet describing the subcarrier index</del>
2	03 <sub>16</sub> Next multiple read
<del>4</del>	<del>04<sub>16</sub> Multiple read block followed by: 2 octets describing the subcarrier index</del>
<del>46</del>	<del>04<sub>16</sub>05<sub>16</sub> Block read followed by: 1 octet 2 octets describing the start subcarrier index 1 octet 2 octets describing the stop subcarrier index</del>
	All other octet values are reserved by ITU-T.

## C.10 Dynamic behaviour

See clause C.10 of ITU-T G.992.3.

## Sub-annex C.Aa

### Specific requirements for an Annex C-based ADSL system operating with a downstream bandwidth of 2208 kHz and an upstream bandwidth of 138 kHz

(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 Annex C because they are unique to an ADSL service that uses a downstream bandwidth up to 2208 kHz (subcarrier 256) and an upstream bandwidth up to 138 kHz (subcarrier 32).

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

##### C.Aa.1.1 ATU-C control parameter settings

(This clause is identical to § A.1.1 of ITU-T G.992.5 Annex A)

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 C.Aa.1. Control Parameters are defined in clause C.8.5.

**Table C.Aa.1 – ATU-C control parameter settings**

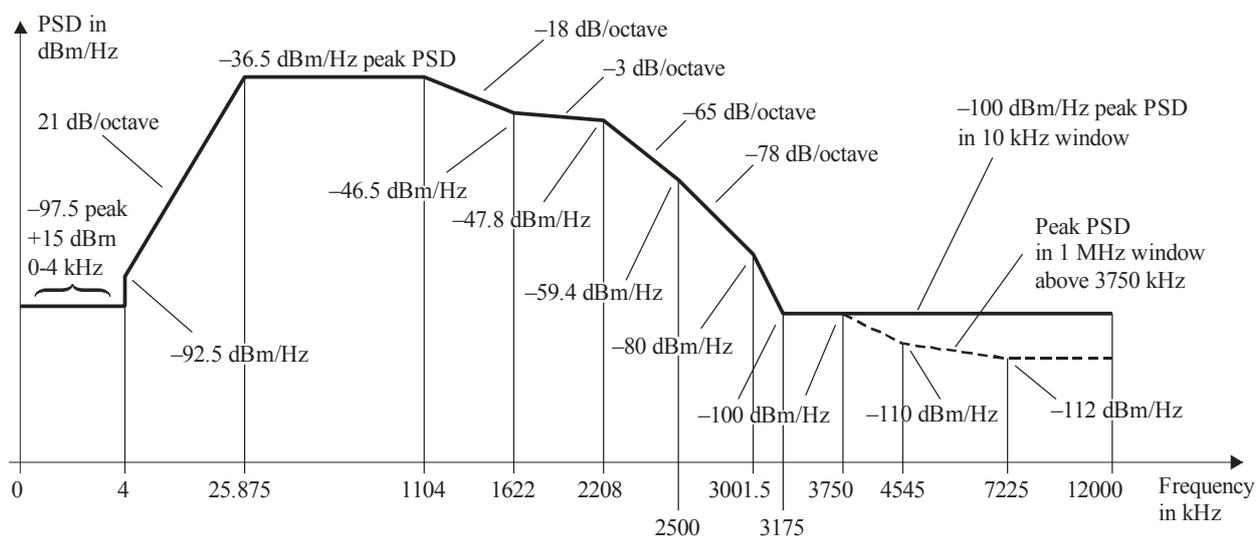
Parameter	Default setting	Characteristics
<i>NSCds</i>	512	
<i>NOMPSDds</i>	−40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause C.8.13.2.
<i>MAXNOMPSDds</i>	−40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause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

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

(This clause is identical to § A.1.2 of ITU-T G.992.5 Annex A)

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 C.Aa.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.



G.992.5(09)\_FA.1

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  $f_i < f \leq f_j$ , 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 C.Aa.1 – ATU-C transmitter PSD mask for overlapped spectrum operation**

### C.Aa.1.2.1 Passband PSD and response

(This clause is identical to § A.2.1 of ITU-T G.992.5 Annex A)

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  $\mu$ s.

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 C.Aa.1.2-1 (informative).

**Table C.Aa.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

#### **C.Aa.1.2.2 Aggregate transmit power**

*(This clause is identical to § A.2.2 of ITU-T G.992.5 Annex A)*

There are three different PSD masks for the ATU-C transmit signal, depending on the type of signal sent (see clause C.Aa.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 dBm (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.

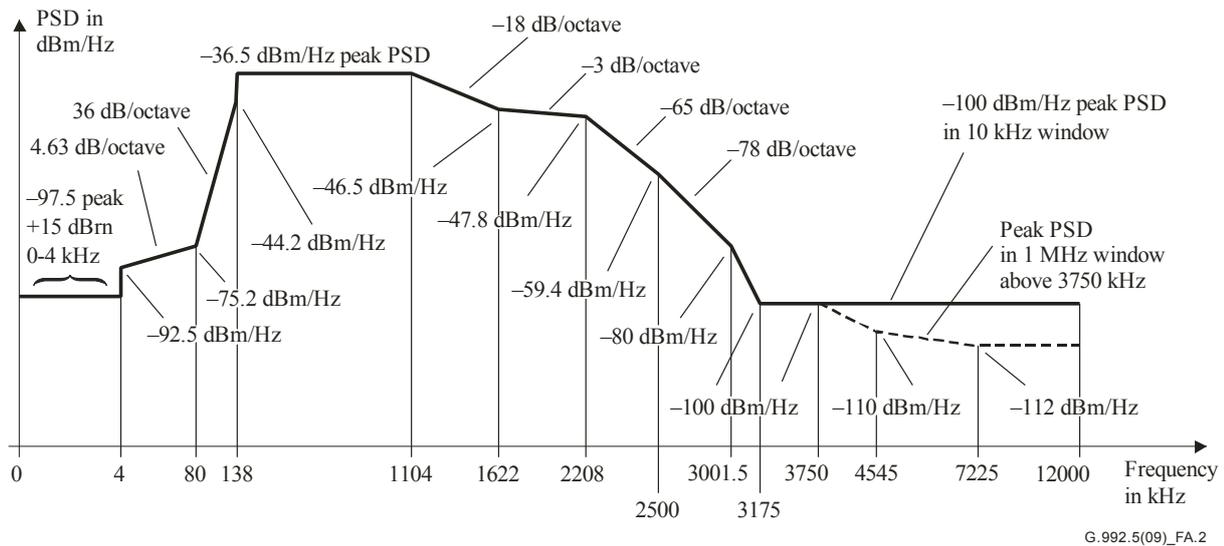
### **C.Aa.1.3 ATU-C transmitter PSD mask for non-overlapped spectrum operation (supplements clause C.8.10)**

*(This clause is identical to § A.1.3 of ITU-T G.992.5 Annex A)*

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

### C.Aa.1.3.1 Passband PSD and response

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

**Table C.Aa.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

### C.Aa.1.3.2 Aggregate transmit power

*(This clause is identical to § A.3.2 of ITU-T G.992.5 Annex A)*

See clause C.Aa.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.

## C.Aa.2 ATU-R functional characteristics (pertains to Clause C.8)

### C.Aa.2.1 ATU-R control parameter settings

*(This clause is identical to § A.2.1 of ITU-T G.992.5 Annex A)*

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 C.Aa.2. Control parameters are defined in clause C.8.5.

**Table C.Aa.2 – ATU-R control parameter settings**

Parameter	Default setting	Characteristics
<i>NSC<sub>us</sub></i>	32	
<i>NOMPSD<sub>us</sub></i>	-38 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause C.8.13.2.

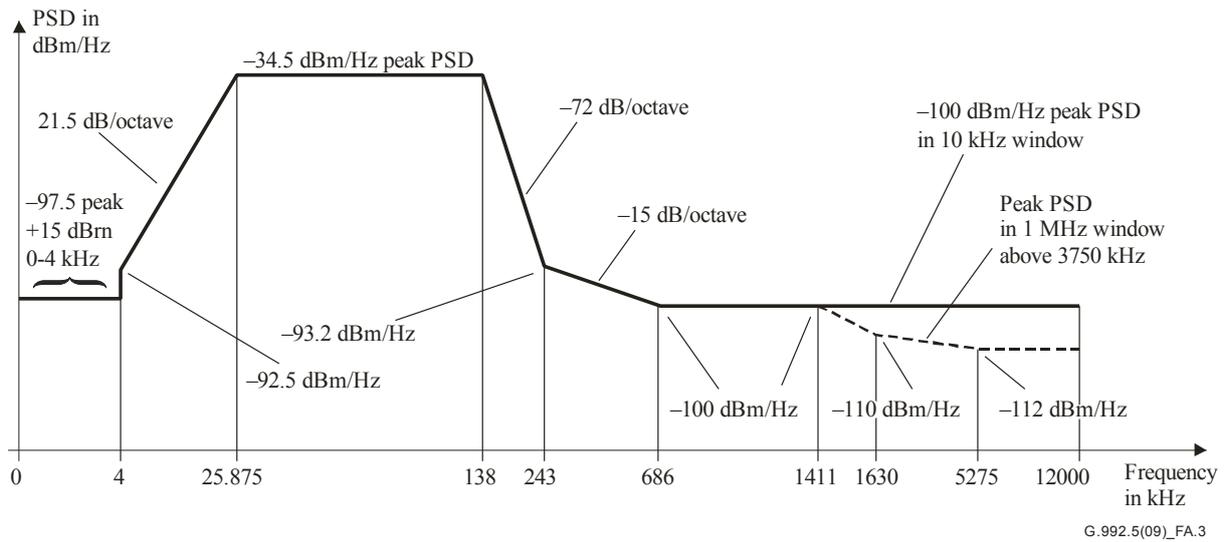
<i>MAXNOMPSD<sub>us</sub></i>	–38 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause C.8.13.2.
<i>MAXNOMATP<sub>us</sub></i>	12.5 dBm	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause C.8.13.2.

### **C.Aa.2.2 ATU-R upstream transmit spectral mask (supplements clause C.8.10)**

*(This clause is identical to § A.2.2 of ITU-T G.992.5 Annex A)*

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 C.Aa.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 C.Aa.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<sub>i</sub>* is applicable for all frequencies satisfying *f<sub>i</sub>* < *f* ≤ *f<sub>j</sub>*, where *f<sub>j</sub>* 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-R interface.

**Figure C.Aa.3 – ATU-R transmitter PSD mask**

### C.Aa.2.2.1 Passband PSD and response

*(This clause is identical to § A.2.2.1 of ITU-T G.992.5 Annex A)*

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:

- $NOMPSD_{us} + 1$  dB, for initialization signals up to and including the channel discovery phase;
- $REFPSD_{us} + 1$  dB, during the remainder of initialization, starting with the transceiver training phase;
- $MAXNOMPSD_{us} - PCBus + 3.5$  dB, during showtime.

The group delay variation over the passband shall not exceed 50  $\mu$ s.

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 C.Aa.2.2-1 (informative).

**Table C.Aa.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

#### **C.Aa.2.2.2 Aggregate transmit power**

*(This clause is identical to § A.2.2.2 of ITU-T G.992.5 Annex A)*

There are three different PSD masks for the ATU-R transmit signal, depending on the type of signal sent (see clause C.Aa.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 dBm (see [ITU-T G.996.1] for method of measurement);
- the aggregate transmit power across the whole passband shall not exceed ( $MAXNOMATP_{us} - PCBus$ ) 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 ( $MAXNOMATP_{us} - PCBus$ ) 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.

### **C.Aa.3 Initialization**

For this annex, no additional requirements apply (relative to Annex C).

## Sub-annex C.Ab

### Specific requirements for an Annex C-based ADSL system operating with a downstream bandwidth of 2208 kHz and an upstream bandwidth of 276 kHz

(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 Annex C because they are unique to an ADSL service that uses a downstream bandwidth up to 2208 kHz (subcarrier 256) and an upstream bandwidth up to 276 kHz (subcarrier 64).

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

##### C.Ab.1.1 ATU-C control parameter settings

(This clause is identical to § A.1.1 of ITU-T G.992.5 Annex A)

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 C.Ab.1. Control Parameters are defined in clause C.8.5.

**Table C.Ab.1 – ATU-C control parameter settings**

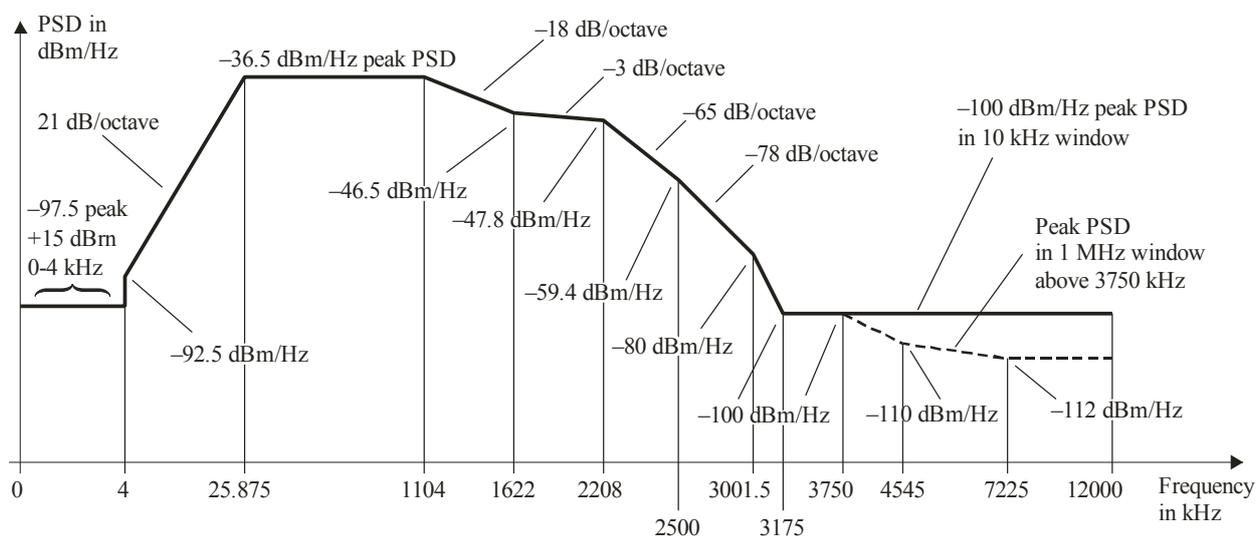
Parameter	Default setting	Characteristics
<i>NSCds</i>	512	
<i>NOMPSDds</i>	−40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause C.8.13.2.
<i>MAXNOMPSDds</i>	−40 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause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

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

(This clause is identical to § A.1.2 of ITU-T G.992.5 Annex A)

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 C.Ab.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.



G.992.5(09)\_FA.1

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  $f_i < f \leq f_j$ , 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 C.Ab.1 – ATU-C transmitter PSD mask for overlapped spectrum operation**

### C.Ab.1.2.1 Passband PSD and response

(This clause is identical to § A.1.2.1 of ITU-T G.992.5 Annex A)

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  $\mu$ s.

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 C.Ab.1.2-1 (informative).

**Table C.Ab.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

### C.Ab.1.2.2 Aggregate transmit power

*(This clause is identical to § A.1.2.2 of ITU-T G.992.35 Annex A)*

There are three different PSD masks for the ATU-C transmit signal, depending on the type of signal sent (see clause C.Ab.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 dBm (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 ( $MAXNOMATP_{ds} - PCB_{ds}$ ) 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.

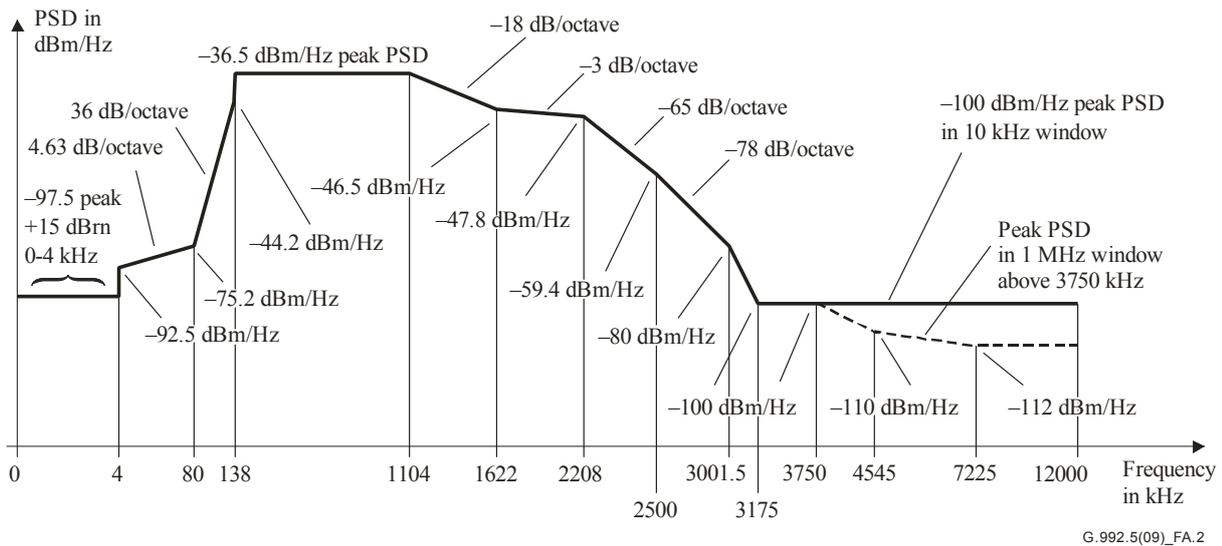
### **C.Ab.1.3 ATU-C transmitter PSD mask for non-overlapped spectrum operation (supplements clause C.8.10)**

*(This clause is identical to § A.1.3 of ITU-T G.992.5 Annex A)*

Figure C.Ab.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 C.Ab.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 C.Ab.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.



G.992.5(09)\_FA.2

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 C.Ab.2 – ATU-C transmitter PSD mask for non-overlapped spectrum operation**

### C.Ab.1.3.1 Passband PSD and response

As defined in clause C.Ab.1.2.1.

NOTE – The downstream and upstream PSD Masks are partially overlapped.

### C.Ab.1.3.2 Aggregate transmit power

(This clause is identical to § A.1.3.1 of ITU-T G.992.5 Annex A)

See clause C.Ab.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.

### C.Ab.2 ATU-R functional characteristics (pertains to clause C.8)

#### C.Ab.2.1 ATU-R control parameter settings

(This clause is identical to § M.2.1 of ITU-T G.992.5 Annex M)

The ATU-R 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 C.Ab.2. Control parameters are defined in clause C.8.5.

**Table C.Ab.2 – ATU-R control parameter settings**

Parameter	Default setting	Characteristics
<i>NSC<sub>us</sub></i>	64	
<i>NOMPSD<sub>us</sub></i>	–38 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause C.8.13.2.
<i>MAXNOMPSD<sub>us</sub></i>	–38 dBm/Hz	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause C.8.13.2.
<i>MAXNOMATP<sub>us</sub></i>	12.5 dBm	Setting may be changed relative to this value during the ITU-T G.994.1 phase, see clause C.8.13.2.

#### C.Ab.2.2 ATU-R upstream transmit spectral mask (supplements clause C.8.10)

(This clause is identical to § M.2.2 of ITU-T G.992.5 Annex M, except that the ATU-R transmit PSD shall comply with EU-64)

The ATU-R transmit PSD shall comply to the spectral mask EU-64 (see Note 1). The spectral mask shall be as defined in Figure C.Ab.1 and Table C.Ab.3.

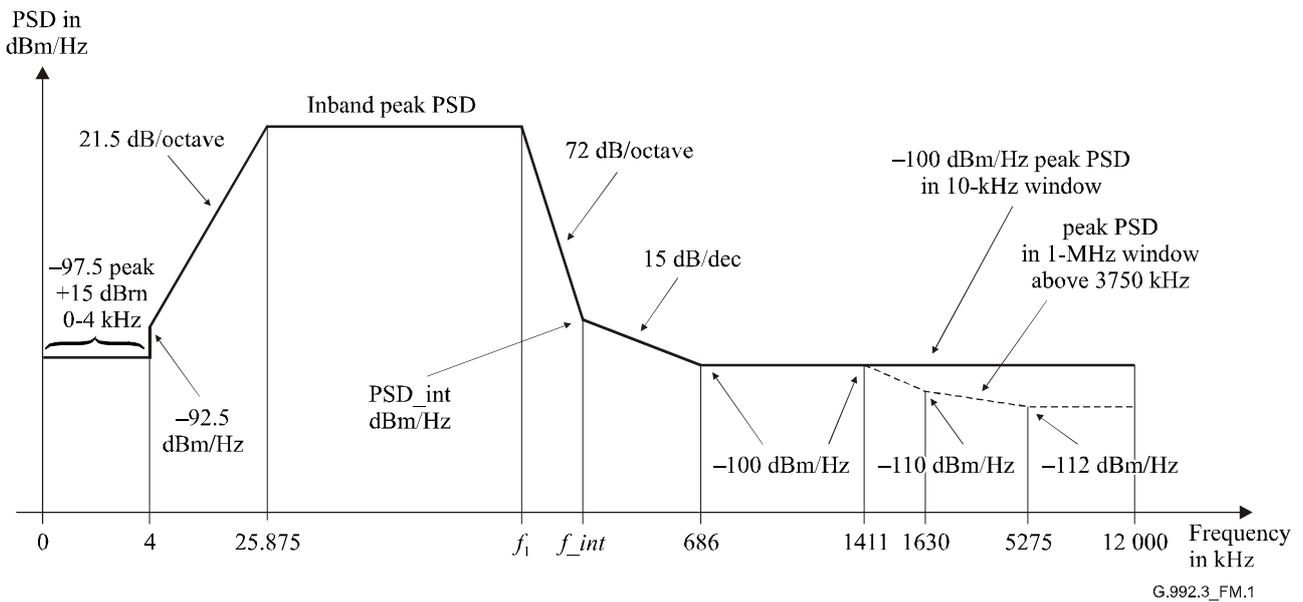
The passband is defined as the band from 25.875 kHz to an upperbound frequency  $f_1$ , defined in Table C.Ab.3. It is the widest possible band used. Limits defined within the passband apply also to any narrower bands used.

Figure C.Ab.1 defines the ATU-R spectral mask 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 C.Ab.3. The *Inband\_peak\_PSD*, *PSD\_int* and the frequencies  $f_1$  and  $f_{int}$  shall be as defined in Table C.Ab.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	<i>Inband_peak_PSD</i>	10 kHz
$f_1$	<i>Inband_peak_PSD</i>	10 kHz
$f_{int}$	<i>PSD_int</i>	10 kHz
686	-100	10 kHz
5275	-100	10 kHz
12 000	-100	10 kHz

Additionally, the PSD mask shall be satisfying 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  $\Omega$ ; the POTS band total power measurement is in 600  $\Omega$ .

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 (see Figure C.Aa.1).

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

**Figure C.Ab.1 – ATU-R transmitter PSD mask**

**Table C.Ab.3 – Inband\_peak\_PSD, PSD\_int and the frequencies f1 and f\_int**

Upstream mask number	Designator	Template nominal PSD (dBm/Hz)	Template maximum aggregate transmit power (dBm)	Inband peak PSD (dBm/Hz)	Frequency f1 (kHz)	Intercept frequency f_int (kHz)	Intercept PSD level PSD_int (dBm/Hz)
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 C.Ab.2.2.2.							

The upstream spectrum bounds default settings in Table C.M.2 apply for all EU-x and shaped PSD masks. Clause C.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) *NOMPSD<sub>us</sub>* 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 C.8.13.2) at least to the template nominal PSD values listed in Table M.3.
- 2) *MAXNOMPSD<sub>us</sub>* shall be a value within the Limit\_PSD\_Mask for PSD shaping (Table M.10) minus 3.5 dB.

**C.Ab.2.2.1 Passband PSD and response**

*(This clause is identical to § M.2.2.1 of ITU-T G.992.35 Annex M, except that the ATU-R transmit PSD shall comply with EU-64)*

See clause C.Aa.2.2.1.

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

**Table C.Ab.4 – ATU-R transmit PSD template definition**

Frequency (kHz)	PSD level (dBm/Hz)
0	-101
4	-101
4	-96
25.875	<i>Inband_peak_PSD</i> -3.5 dB
<i>f1</i>	<i>Inband_peak_PSD</i> -3.5 dB
<i>f_int_templ</i>	<i>PSD_int_templ</i>
686	-100
1411	-100
1630	-110
5275	-112
12000	-112

**Table C.Ab.5 – The  $f_{int\_templ}$  and  $PSD_{int\_templ}$  values for the ATU-R transmit PSD template**

<b>Upstream mask number</b>	<b>Designator</b>	<b>Template intercept frequency <math>f_{int\_templ}</math> (kHz)</b>	<b>Template intercept PSD level <math>PSD_{int\_templ}</math> (dBm/Hz)</b>
9	EU-64	475.99	-97.6

### **C.Ab.2.2.2 Aggregate transmit power**

*(This clause is identical to § M.2.2.2 of ITU-T G.992.5 Annex M)*

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

- the aggregate transmit power in the voiceband, measured at the U-R interface, and that is delivered to the plain old telephone service (POTS) interface, shall not exceed +15 dBm (see [ITU-T G.996.1] for method of measurement);
- the aggregate transmit power across the whole passband shall not exceed ( $MAXNOMATP_{us} - PC_{Bus}$ ) 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 ( $MAXNOMATP_{us} - PC_{Bus}$ ) 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.

### **C.Ab.3 Initialization**

For this annex, no additional requirements apply (relative to Annex C).

## Annex C.K

### TPS-TC functional descriptions specific to an Annex C-based system

(This annex forms an integral part of this Recommendation)

See Annex C.K of ITU-T G.992.3, modifying Table C.K.11 follows:

**Table C.K.11 – Mandatory downstream configuration for ATM-TC function #0**

Parameter	Capability
<i>type<sub>n</sub></i>	2
<i>net_min<sub>n</sub></i>	<i>net_min<sub>n</sub></i> shall be supported for all valid framing configurations up to and equal to <del>8 Mbit/s</del> 16 Mbit/s (see Note).
<i>net_max<sub>n</sub></i>	<i>net_max<sub>n</sub></i> shall be supported for all valid framing configurations up to and equal to <del>8 Mbit/s</del> 16 Mbit/s (see Note).
<i>net_reserve<sub>n</sub></i>	<i>net_reserve<sub>n</sub></i> shall be supported for all valid framing configurations up to and equal to <del>8 Mbit/s</del> 16 Mbit/s.
<i>delay_max<sub>n</sub></i>	All valid values shall be supported.
<i>error_max<sub>n</sub></i>	All valid values shall be supported.
<i>INP_min<sub>n</sub></i>	0, 1/2, 1, 2
<i>INP_no_erasure_not_required<sub>n</sub></i>	0
<i>IMA_flag</i>	All valid values shall be supported.
<i>jitter_max<sub>n</sub></i>	All valid values shall be supported.
<i>CIpolicy<sub>n</sub></i>	0
NOTE – Support for values above the required net data rate is optional and allowed.	

## **Appendix C.IV**

### **Example overlapped PSD masks for use in a TCM-ISDN crosstalk environment**

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

*See Appendix C.I.V of ITU-T G.992.3.*





## 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
<b>Series G</b>	<b>Transmission systems and media, digital systems and networks</b>
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
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