O-P-MEDLEY and R-P-MEDLEY shall be followed by O-P-SYNCHRO 6 and R-P-SYNCHRO 6, respectively. O-P-SYNCHRO 6 and R-P-SYNCHRO 6 shall be as defined in clause 12.3.5.3.

After transmitting O-P-SYNCHRO 6, the VTU-O shall transmit O-P-TRAINING 3. While transmitting O-P-TRAINING 3, the VTU-O shall send O-IDLE over the SOC for at least 256 DMT symbols, and shall then send O-MSG-LD. Similarly, after transmitting R-P-SYNCHRO 6, the VTU-R shall transmit R-P-TRAINING 3. While transmitting R-P-TRAINING 3, the VTU-R shall send R-IDLE over the SOC. The VTU-R shall acknowledge the reception of O-MSG-LD by sending R-MSG-LD. Both VTUs shall use the RQ mode, as specified in clause 12.2.2.2.

The VTU-O shall acknowledge the reception of R-MSG-LD by transmitting O-P-SYNCHRO 7, which also indicates that the VTU-O has completed the channel analysis and exchange phase. The VTU-R acknowledges O-P-SYNCHRO 7 by transmitting R-P-SYNCHRO 7, indicating full completion of the loop diagnostic mode.

Table 12-76 – VTU-O signals and SOC messages in the channel analysis and exchange phase of loop diagnostic mode

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages and IDLE flags	SOC state
O-P-MEDLEY	Non-periodic	80 000	O-IDLE	Active
O-P-SYNCHRO 6	Non-periodic	15	None	Inactive
O-P-TRAINING 3	Non-periodic	Variable	O-MSG-LD	Active (RQ)
O-P-SYNCHRO 7	Non-periodic	15	None	Inactive

Table 12-77 – VTU-R signals and SOC messages during the channel analysis and exchange phase of loop diagnostic mode

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages and IDLE flags	SOC state
R-P-MEDLEY	Non-periodic	80 000	R-IDLE	Active
R-P-SYNCHRO 6	Non-periodic	15	None	Inactive
R-P-TRAINING 3	Non-periodic	Variable	R-MSG-LD	Active (RQ)
R-P-SYNCHRO 7	Non-periodic	15	None	Inactive

12.4.3.1 SOC messages exchanged during the channel analysis and exchange phase of loop diagnostic mode

12.4.3.1.1 VTU-O messages

In the loop diagnostic mode, the VTU-O shall send the O-MSG-LD message containing the upstream test parameters defined in clause 11.4.1.

The information fields of O-MSG-LD shall be as shown in Table 12-78.

Table 12-78 – Description of message O-MSG-LD

	Field name	Format
1	Message descriptor	Message code
2	Hlin($k \times G \times \Delta f$)	6 × 512
3	SNR($k \times G \times \Delta f$)	512
4	LATN-pb	(2 × 5) bytes
5	SATN-pb	(2 × 5) bytes
6	SNRM and SNRM-pb	2 + (2 × 5) bytes
7	ATTNDR	4 bytes
8	ACTATP	2 bytes

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Hlin($k \times G \times \Delta f$)" indicates the parameter Hlin for 512 subcarrier groups in the upstream direction. The parameter Hlin for each group shall be mapped to 6 octets as [*scale a(k) b(k)*], where *scale*, *a(k)*, and *b(k)* are 16-bit values as specified in clause 11.4.1.1.1. The 6 octets representing Hlin values for different groups shall be mapped to Field #2 so that they are transmitted in ascending order of group index *k*, for *k* = 0 to 511. The groups shall be formed as specified in clause 11.4.1.

Field #3 "SNR($k \times G \times \Delta f$)" indicates the parameter SNR for 512 subcarrier groups in the upstream direction. The SNR for each group shall be represented as an 8-bit value as specified in clause 11.4.1.1.3, and mapped into 1 octet. The octets representing SNR values for different groups shall be mapped to Field #3 so that they are transmitted in ascending order of group index *k*, for *k* = 0 to 511. The groups shall be formed as specified in clause 11.4.1. The values of SNR for the groups containing at least one subcarrier that is not in the MEDLEYus set shall be set to FF_{16}.

Field #4 "LATN-pb" shall indicate the parameter LATN_U(*m*) for each of 5 potentially available upstream bands. The parameter LATN_U(*m*) for each band shall be represented as a 10-bit value as specified in clause 11.4.1.1.4, and mapped into 2 octets by adding six MSBs equal to 0. The pairs of octets representing LATN_U(*m*) values for different bands shall be mapped to Field #4 as described in Table 11-29. The value 0000_{16} shall be used to indicate disabled bands. Octets indicated as reserved in Table 11-29 shall be set to ZERO in the transmitter and ignored by the receiver.

Field #5 "SATN-pb" shall indicate the parameter SATN_U(*m*) for each of 5 potentially available upstream bands. The parameter SATN_U(*m*) for each band shall be represented as a 10-bit value as specified in clause 11.4.1.1.5, and mapped into 2 octets by adding six MSBs equal to 0. The pairs of octets representing SATN_U(*m*) values for different bands shall be mapped to Field #5 as described in Table 11-29. The value 0000_{16} shall be used to indicate disabled bands. Octets indicated as reserved in Table 11-29 shall be set to ZERO in the transmitter and ignored by the receiver.

Field #6 "SNRM and SNRM-pb" shall indicate the overall upstream SNRM value, as specified in clause 11.4.1.1.6.2, and parameter SNRM_U(*m*), as specified in clause 11.4.1.1.6.3. The first two octets shall indicate parameter SNRM and the rest of the octets shall indicate parameter SNRM_U(*m*) for each of 5 potentially available upstream bands. The value of SNRM shall be represented as a 10-bit value as specified in clause 11.4.1.1.6.2. The parameter SNRM_U(*m*) for each band shall be represented as a 10-bit value as specified in clause 11.4.1.1.6.3. Both SNRM and SNRM_U(*m*) shall be mapped into 2 octets by adding six MSBs equal to the sign bit of the SNRM or SNRM_U(*m*) 10-bit representations, respectively. The pairs of octets representing SNRM_U(*m*) values for different bands shall be mapped to Field #6 as described in Table 11-29. The value 0000_{16} shall be used to indicate disabled bands. Octets indicated as reserved in Table 11-29 shall be set to ZERO in the transmitter and ignored by the receiver.

Field #7 "ATTNDR" shall indicate the parameter ATTNDR in the upstream direction computed as specified in clause 11.4.1.1.7 for all subcarriers from the MEDLEYus set. The parameter shall be represented as a 32-bit value as defined in clause 11.4.1.1.7.

Field #8 "ACTATP" shall indicate the parameter ACTATP in the upstream direction computed as specified in clause 11.4.1.1.8 for all subcarriers from the MEDLEYus set. The parameter shall be represented as a 10-bit value as defined in clause 11.4.1.1.8 and mapped to the 2-byte Field #8 by adding six MSBs equal to the sign bit of the ACTATP representation.

12.4.3.1.2 VTU-R messages

In the loop diagnostic mode, the VTU-R shall send the R-MSG-LD message containing the downstream test parameters defined in clause 11.4.1.

The information fields of R-MSG-LD shall be as shown in Table 12-79.

Table 12-79 – Description of message R-MSG-LD

	Field name	Format
1	Message descriptor	Message code
2	Hlin($k \times G \times \Delta f$)	6 × 512
3	SNR($k \times G \times \Delta f$)	512
4	LATN-pb	(2 × 5) bytes
5	SATN-pb	(2 × 5) bytes
6	SNRM and SNRM-pb	2 + (2 × 5) bytes
7	ATTNDR	4 bytes
8	ACTATP	2 bytes

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Hlin($k \times G \times \Delta f$)" indicates the parameter Hlin for 512 subcarrier groups in the downstream direction. The parameter Hlin for each group shall be mapped into 6 octets as [*scale a(k) b(k)*], where *scale*, *a(k)*, and *b(k)* are 16-bit values as specified in clause 11.4.1.1.1. The 6 octets representing Hlin values for different groups shall be mapped to Field #2 so that they are transmitted in ascending order of group index k, for k = 0 to 511. The groups shall be formed as specified in clause 11.4.1.

Field #3 "SNR($k \times G \times \Delta f$)" indicates the parameter SNR for 512 subcarrier groups in the downstream direction. The SNR for each group shall be represented as an 8-bit value as specified in clause 11.4.1.1.3, and mapped into a single octet. The octets representing SNR values for different groups shall be mapped to Field #3 so that they are transmitted in ascending order of group index k, for k = 0 to 511. The groups shall be formed as specified in clause 11.4.1. The values of SNR for the groups containing at least one subcarrier that is not in MEDLEYds set shall be set to FF_{16}.

Field #4 "LATN-pb" shall indicate the parameter LATN_D(m) for each of 5 potentially available downstream bands. The parameter LATN_D(m) for each band shall be represented as a 10-bit value as specified in clause 11.4.1.1.4, and mapped into 2 octets by adding six MSBs equal to 0. The pairs of octets representing LATN_D(m) values for different bands shall be mapped to Field #4 as described in Table 11-29. The value 0000_{16} shall be used to indicate the disabled bands. Octets indicated as reserved in Table 11-29 shall be set to ZERO in the transmitter and ignored by the receiver.

Field #5 "SATN-pb" shall indicate the parameter SATN_D(m) for each of 5 potentially available downstream bands. The parameter SATN_D(m) for each band shall be represented as a 10-bit value as specified in clause 11.4.1.1.5, and mapped into 2 octets by adding six MSBs equal to 0. The pairs of octets representing SATN_D(m) values for different bands shall be mapped to Field #5 as described in Table 11-29. The value 0000_{16} shall be used to indicate the disabled bands. Octets indicated as reserved in Table 11-29 shall be set to ZERO in the transmitter and ignored by the receiver.

Field #6 "SNRM and SNRM-pb" shall indicate the overall downstream SNRM value, as specified in clause 11.4.1.1.6.2, and the parameter SNRM_D(m), as specified in clause 11.4.1.1.6.3. The first two octets shall indicate parameter SNRM, and the rest of the octets shall indicate parameter SNRM_D(m) for each of 5 potentially available downstream bands. The value of SNRM shall be represented as a 10-bit value as specified in clause 11.4.1.1.6.2. The value of SNRM_D(m) for each band shall be represented as a 10-bit value as specified in clause 11.4.1.1.6.3. Both SNRM and SNRM_D(m) shall be mapped into 2 octets by adding six MSBs equal to the sign bit of the SNRM and SNRM_D(m) 10-bit representation, respectively. The pairs of octets representing SNRM_D(m) values for different bands shall be mapped to Field #6 as described in Table 11-29. The value 0000_{16} shall be used to indicate the disabled bands. Octets indicated as reserved in Table 11-29 shall be set to ZERO in the transmitter and ignored by the receiver.

Field #7 "ATTNDR" shall indicate the parameter ATTNDR in the downstream direction computed as specified in clause 11.4.1.1.7 for all subcarriers from the MEDLEYds set. The parameter shall be represented as a 32-bit value as defined in clause 11.4.1.1.7.

Field #8 "ACTATP" shall indicate the parameter ACTATP in the downstream direction computed as specified in clause 11.4.1.1.8 for all subcarriers from the MEDLEYds set. The parameter shall be represented as a 10-bit value as defined in clause 11.4.1.1.8 and mapped into the 2-byte Field #8 by adding six MSBs equal to the sign bit of the ACTATP representation.

12.4.3.2 Signals transmitted during the channel analysis and exchange phase of loop diagnostic mode

The O-P-MEDLEY and R-P-MEDLEY signals shall be as defined in clause 12.3.5.3 for initialization with the following exceptions:

- the duration of O-P-MEDLEY and R-P-MEDLEY shall each be 80 000 symbols; and
- the SOC message mapping shall be as defined in clause 12.4.1.1.

O-P-SYNCHRO 6, R-P-SYNCHRO 6, O-P-SYNCHRO 7 and R-P-SYNCHRO 7 shall be as defined in clause 12.3.5.3 for initialization.

12.4.3.2.1 O-P-TRAINING 3

The O-P-TRAINING 3 signal is used to send the O-MSG-LD SOC message. During transmission of O-P-TRAINING 3, the SOC is in its active state.

The duration of O-P-TRAINING 3 is variable. The VTU-O terminates O-P-TRAINING 3 by transmitting O-P-SYNCHRO 7.

O-P-TRAINING 3 shall be composed of all subcarriers in the MEDLEYds set. These subcarriers shall be modulated by 4-QAM with SOC bit mapping as described in clause 12.4.1.1.

The constellation points of all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

The symbol length shall be $2N_{ds}+L_{CE}$ samples. Windowing shall be applied at the transmitter, and the overall window length shall be equal to β_{ds} (see clause 10.4.4). The values of $2N_{ds}$, L_{CE}, β_{ds} and cyclic prefix length shall be set to the values communicated by the VTU-O in O-PRM-LD.

The transmit PSD of the MEDLEYds subcarriers in O-P-TRAINING 3 shall be the same as for O-P-TRAINING 2.

12.4.3.2.2 R-P-TRAINING 3

The R-P-TRAINING 3 signal is used to send the R-MSG-LD SOC message. During transmission of R-P-TRAINING 3, the SOC is in its active state.

The duration of R-P-TRAINING 3 is variable. The VTU-O terminates R-P-TRAINING 3 by transmitting R-P-SYNCHRO 7.

R-P-TRAINING 3 shall be composed of all subcarriers in the MEDLEYus set. These subcarriers shall be modulated by 4-QAM with SOC bit mapping as described in clause 12.4.1.1.

The constellation points of all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler, as described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

The symbol length shall be $2N_{us}+L_{CE}$ samples. Windowing shall be applied at the transmitter, and the overall window length shall be equal to β_{us} (see clause 10.4.4). The values of $2N_{us}$, β_{us} and cyclic prefix length shall be set to the values communicated by the VTU-R in R-PRM-LD. The value of L_{CE} shall be as communicated by the VTU-O in O-PRM-LD.

The transmit PSD of the MEDLEYus subcarriers in R-P-TRAINING 3 shall be the same as for R-P-TRAINING 2.

12.5 Fast start-up

For further study.

13 On-line reconfiguration (OLR)

On-line reconfiguration allows changes to the PMD without interruption of service and without errors. The defined procedures for on-line reconfiguration of the PMD function provide means for adapting to slowly varying channel conditions. They provide transparency to the PMS-TC, TPS-TC and higher layers by providing means for configuration parameter changes that introduce no transport errors, no latency changes, and no interruption of service.

13.1 Types of on-line reconfiguration

Types of OLR include bit swapping, SRA, and SOS.

Bit swapping reallocates bits and power (i.e., margin) among the allowed subcarriers without modification of the higher layer features of the physical layer. Bit swapping reconfigures the bit and gain (b_i, g_i) parameters without changing any other PMD or PMS-TC control parameters. After a bit swapping reconfiguration, the total data rate $(\Sigma L_p) \times f_s$ is unchanged, and the total data rate on each latency path ($L_p \times f_s$) is unchanged.

Because bit swapping is used autonomously to maintain the operating conditions of the VTU during changing environment conditions, bit swapping is a mandatory capability. The procedure for bit swapping is defined in clause 11.2.3.3 (OLR commands) and shall be implemented using Type 1 OLR messages as shown in Tables 11-5 and 11-6.

NOTE – When the ROC is enabled, bits L_0 and L_1 do not share the same subcarrier (see clause 10.3.1).

SRA is used to reconfigure the total data rate (ΣL_p) by modifying the framing parameters (L_p) and modifications to the bits and fine gains (b_i, g_i) parameters. Since the total data rate is modified, at least one latency path (or more) will have a new data rate (L_p) after the SRA. Since SRA is optional, the ability to support it is identified during the initialization procedure. The procedure for SRA is defined in clause 11.2.3.3 (OLR commands) and shall be implemented using Type 3 OLR messages as shown in Tables 11-6 and 11-7.

Save our showtime (SOS) provides the receiver with a means to rapidly perform a bit loading reduction in a specified part of the frequency spectrum. This can be used in case of sudden noise increases. During initialization, the VTUs may define a number of SOS tone groups in both the upstream and downstream directions. An SOS request reduces the bit loading on all tones in a group by the same number of bits (multiple groups can be changed in a single command). The SOS request can also explicitly reconfigure the framing parameters L_p and the interleaver depth D_p in each of the latency paths.

NOTE 1 – For a wideband sudden noise increase, it is a goal that VTUs improve the data transmission within 1 second after the SOS trigger to achieve a BER≤1E-7. The desired data rate after this time is at least 80% of the data rate that would be obtained if the VTU were to (re-) initialize in the high noise condition using the same Transmit PSD level.

NOTE 2 – Sudden noise increases of up to 30 dB may occur in real networks.

Interleaver reconfiguration (within SRA) allows to dynamically change the interleaver depth D_p on one or more latency paths. SRA may be accompanied by a change of the framing parameters T_p, G_p and B_{p0}. Interleaver reconfiguration and modification of framing parameters T_p, G_p and B_{p0} are optional.

The procedure for interleaver reconfiguration is defined in clauses 9.4.1 and 11.2.3.3 (OLR commands) and shall be implemented using Type 3 OLR messages as shown in Tables 11-6 and 11-7.

13.2 Control parameters

13.2.1 Control parameters controlled by the OLR procedures

On-line reconfiguration of the PMD is accomplished by a coordinated change to the bits and gain values on two or more subcarriers. The bit and gain parameters described in Table 13-1 may be changed through on-line reconfiguration within the limits described.

Table 13-1 – Reconfigurable control parameters of the PMD function

Parameter	Definition
b_i	The number of bits per subcarrier with valid values all integers in the [0 ... 15] range. A change of the b_i values may be performed without modifying the L value (e.g., bit swap) or with a change of the L value (e.g., seamless rate adaptation).
g_i	The subcarrier gain adjustments with valid values in the [−14.5 ... +2.5] dB range.

The receiver shall support all valid b_i values and shall support increment and decrement of b_i values in steps of 1 bit in the OLR procedures. Incrementing or decrementing by steps larger than 1 bit are optional.

NOTE – The support of $b_i = 0$ is mandatory for the receiver in order to meet the requirement of 10^{-7} bit error ratio specified in clause 9.8.

The transmitter shall support of all valid values of b_i and shall support increment and decrement of b_i values in any step in the OLR procedures.

The updated bits and gains table shall comply with the bits and gains table requirements listed in clauses 10.3.1 and 10.3.4.

On-line reconfiguration of the PMS-TC is accomplished by a coordinated change to the value of one or more of the framing parameters shown in Table 13-2. The framing parameters displayed in Table 13-2 may be changed through on-line reconfiguration within the limits described.

Table 13-2 – Reconfigurable framing parameters of the PMS-TC function

Parameter	Definition
L_p	If latency path #*p* is used, the number of bits from latency path #*p* transmitted in each DMT symbol may be increased or decreased; the value of L_p is determined by the total data rate assigned for the latency path.
D_p	The interleaver depth on latency path *p* may be increased or decreased, as long as the resulting interleaver delay on that latency path does not exceed the bounds determined during initialization.
T_p	The number of MDFs in an overhead subframe: This value can be increased or decreased within the set of valid values (see Table 9-8).
G_p	The total number of overhead octets in an OH subframe: This value can be increased or decreased within the set of valid values (see Table 9-8).
B_{p0}	The total number of octets from bearer channel #0 in a mux data frame: This value can be increased or decreased within the set of valid values (see Table 9-8).
NOTE – Any change in L_p, T_p, G_p, and B_{p0} values shall be such that the length of the MDF (as defined in Table 9-8) remains unchanged for all active latency paths.	

13.2.2 Parameters controlling the OLR procedures

The list of parameters controlling OLR procedure Type 3 is presented in Table 13-3.

Table 13-3 – Control parameters controlling the OLR procedures

Parameter	Definition
RA-USNRM *RA-UTIME*	The rate adaptation upshift noise margin and time interval (defined in [ITU-T G.997.1]). The parameter can be different for the VTU-O (*RA-USNRMus* and *RA-UTIMEus*) and the VTU-R (*RA-UTIMEds*, *RA-USNRMds*). VTU-O: Configured through CO-MIB. VTU-R: Configured through CO-MIB and communicated to the VTU-R during initialization (O-MSG 1). The valid values for *RA-USNRMus* and *RA-USNRMds* are values between 0 and 31.0 dB in steps of 0.1 dB. The valid values for *RA-UTIMEus* and *RA-UTIMEds* are values between 0 and 16 383 s in steps of 1 s.
RA-DSNRM *RA-DTIME*	The rate adaptation downshift noise margin and time interval (defined in [ITU-T G.997.1]). The parameter can be different for the VTU-O (*RA-DSNRMus* and *RA-DTIMEus*) and the VTU-R (*RA-DTIMEds*, *RA-DSNRMds*). VTU-O: Configured through the CO-MIB. VTU-R: Configured through the CO-MIB and communicated to the VTU-R during initialization (O-MSG 1). The valid values for *RA-DSNRMus* and *RA-DSNRMds* are values between 0 and 31.0 dB in steps of 0.1 dB. The valid values for *RA-DTIMEus* and *RA-DTIMEds* are values between 0 to 16 383 s in steps of 1 s.

Table 13-3 – Control parameters controlling the OLR procedures

Parameter	Definition
$DVmax_n$	The maximum allowed value for the delay variation DV_n of bearer channel #*n*. It ranges from 0.1 to 25.4 in steps of 0.1 ms. The value 25.5 indicates that no delay variation bound is imposed. The parameter can be different for the VTU-O and the VTU-R. VTU-O: Configured through the CO-MIB. VTU-R: Configured through the CO-MIB and communicated to the VTU-R during initialization (O-TPS).

13.3 Timing of changes in subcarrier configuration

In both the upstream and the downstream directions, the reconfiguration of the PMD functions shall take effect starting with the tenth symbol that follows transport of the Syncflag for OLR Type 1. As defined in clause 10.2, the sync symbol is transmitted after every 256 data symbols. The reconfiguration of the PMD function shall take effect starting with the symbol at symbol count 9 in the next DMT superframe, where the first symbol in each DMT superframe is the symbol at symbol count 0.

For OLR Type 3, when performed in the latency path *p*, the change in L_p values and b_i, g_i values shall take effect starting from the 66th symbol that follows the Syncflag, i.e., the symbol with symbol count 65 in the DMT superframe following the Syncflag, where the first symbol in the DMT superframe is the symbol at symbol count 0.

The change of framing parameters T_p, G_p and B_{p0} shall take effect on the first OH frame of the first OH superframe that follows the 66th DMT symbol after the Syncflag.

The change in D_p shall take effect on the first byte of an interleaved RS codeword (byte *k* as defined in clause 9.4.1). This codeword shall be determined as follows:

- For a decrease in interleaver depth, this shall be the first RS codeword that starts at or after the beginning of the 66th DMT symbol.
- For an increase in interleaver depth, this shall be the last RS codeword that starts at or before the beginning of the 66th DMT symbol.

The location of the RS codeword relative to the 66th DMT symbol is illustrated in Figure 13-1.

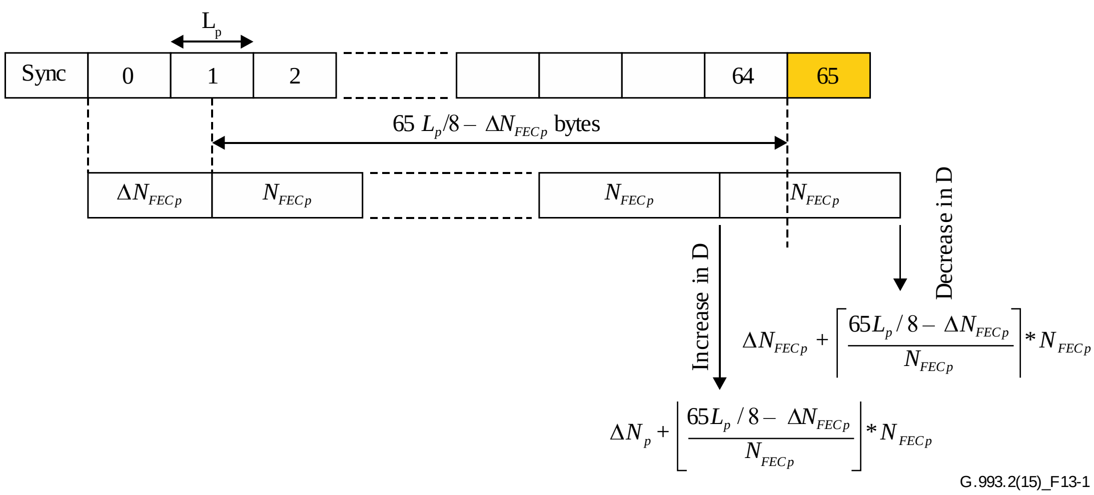

Figure 13-1 – Finding the byte where the change in D_p is activated

Figure 13-1 shows the DMT symbol counter and the byte counter at which the interleaver depth change is activated, relative to the Syncflag. For an increase in depth, the change in D_p will always happen at the same time or before the change in L_p, but as close to it as possible (i.e., the change in D_p happens during the DMT symbol with count 64 or sooner). Likewise, for a decrease in depth, the change in D_p will always happen at the same time or after the change in L_p, but as close to it as possible (i.e., the change in D_p happens during the DMT symbol with count 65 or later).

For OLR Type 4 (SOS), the change in L_p values and b_i values shall take effect starting from the 66th symbol that follows the Syncflag, i.e., the symbol with symbol count 65 in the DMT superframe following the Syncflag, where the first symbol in the DMT superframe is the symbol at symbol count 0.

For all the used tones in an SOS tone group *k*, the same b_i reduction $\Delta b(k)$ is applied, except for tones that belong to the ROC. Specifically, the new $b_i'=b_i-\Delta b(k)$. If the new b_i' value is <2, it shall be set to 0. Thus, no new 1-bit loading will be created in SOS. If the resulting b_i' contains an odd number of 1-bit constellation points and trellis is enabled, the last (according to reordered tone ordering table) 1-bit constellation should be set to $b_i'=0$.

When the SOS request is executed in multiple steps, the tones shall be updated in groups of size G_{SOS}, where G_{SOS} is the minimum of the values indicated by VTU-R and VTU-O in R-MSG2 and O-MSG1 respectively. The tones shall be updated in the order determined by the reordered tone ordering table. To insure that the bit-loading after each step contains an even number of 1-bit constellation, the tone with the unpaired 1-bit constellation shall be removed from this step and included in the next step.

The change in bit loading for the first group of tones shall be done at the 66th symbol that follows the Syncflag. The change for subsequent groups shall be done T_{SOS} symbols after the execution of the previous group (on the symbol count $65 + s \times T_{SOS}$, s = 1, 2, … N-1, sync symbols are not counted) until all tones have been changed. The last group may have less than G_{SOS} tones. The value of T_{SOS} depends on the selected value of G_{SOS} and shall be as presented in Table 13-4.

NOTE – The number of steps N depends on the total number of tones, W, subject to bit loading change during the SOS. It can be computed as N = ceiling(W/GSOS). Assuming the maximum number of tones in the transmit direction for the band plans defined in Annexes A, B and C, N does not exceed 12 for GSOS = 256, 6 for GSOS = 512, and 3 for GSOS = 1 024.

Table 13-4 – G_{SOS} and associated values of T_{SOS}

G_{SOS}	T_{SOS} (4.3125 kHz)	T_{SOS} (8.625 kHz)
256	48	96
512	72	144
1 024	96	192
All tones	N/A	N/A

In the case of multi-step, the value of D (interleaver depth) shall be changed with the last group of tones. The change shall happen at the same symbol or at the first opportunity after the change of bit loading for the last group of tones (during the DMT symbol with count $65 + (N-1) \times T_{SOS}$ or later).

When the SOS request is executed in a single step, the value of D shall be changed as described in this clause for OLR type 3.

After it has received an SOS request, the VTU shall respond within 200 ms with either a Syncflag or a reject type 4 invalid parameters response (see Table 11-8). When the execution is done in multiple steps, the total time between reception of the message and full execution of the command shall not exceed 300 ms. In addition, the VTU shall respond within 146.5 ms after it has received an SOS request with either a Syncflag or a reject type 4 invalid parameters response. The response shall be sent at the first opportunity after the SOS request is received provided there is enough time to execute the first step of a multi-step activation.

During the transition of OLR type 4 in single or multiple steps, bit errors may occur. Once the transition is completed, the VTU shall operate at a BER not exceeding the nominal BER, unless the line conditions do not allow it.

13.4 Receiver initiated procedure

If a VTU receiver initiates a reconfiguration, it computes the necessary change in the related parameters (e.g., bits and gains table) and requests this change in the transmit PMD function of the VTU at the other end of the line. After it receives a positive acknowledgment, as specified in clause 11.2.3.3, the VTU shall change the relevant control parameters of its own receive PMD function and the PMS-TC function at the time specified in clause 13.3.

A VTU receiver may initiate an OLR Type 1 (Bit Swapping). A bit swap request shall change only the bits and gains table. It shall not modify the *L* value. Bit swapping reconfigurations involve changes of only the PMD sublayer configuration parameters. They do not change the TPS-TC and PMS-TC sublayer configuration parameters.

The transmit PMD function shall support bit swaps requested by the receive PMD function.

If OLR type 3 (SRA) is supported (in downstream or upstream direction, respectively), and enabled (through RA-MODE=3), a VTU receiver shall initiate an SRA when the conditions in clause 13.4.1 or clause 13.4.2 are satisfied.

If OLR type 3 (SRA) is supported (in downstream or upstream direction, respectively), and enabled (through RA-MODE=4), a VTU receiver shall initiate an SRA when the conditions in clause 13.4.1, clause 13.4.2 or clause 13.4.3 are satisfied. A VTU receiver may initiate a SRA when the conditions in clause 13.4.4 are satisfied.

If OLR type 4 (SOS) is supported (in downstream or upstream direction, respectively), and enabled (through RA-MODE=4), a VTU receiver shall initiate an SOS when the conditions in clause 13.4.3 are satisfied.

A VTU receiver shall only send OLR request commands that meet all of following constraints:

- Impulse noise protection ≥ Minimum impulse noise protection for all bearer channels;
- Delay ≤ Maximum delay for all bearer channels;

A VTU receiver shall only send SOS requests that meet the following constraints:

- Net data rate (NDR_n) ≥ Minimum SOS net data rate ($MIN\text{-}SOS\text{-}BR_n$) for all bearer channels;

NOTE – An SOS request could result in a message overhead data rate that is temporarily below the configured minimum message overhead data rate. This will be corrected by a subsequent SRA procedure. See clause 13.4.3.3.

A VTU receiver shall only send SRA requests that meet the following constraints:

- Maximum net data rate ≥ Net data rate ≥ Minimum net data rate for all bearer channels, unless the actual net data rate is below the minimum net data rate as a result of an SOS procedure. In that case, SRA is only allowed to ask for rate increases, but the requested Net data rate is allowed to be below Minimum net data rate;
- Message overhead data rate ≥ Minimum message overhead data rate;
- $DV_n \leq DVmax_n$ for all bearer channels.

13.4.1 Receiver Initiated SRA downshift procedure

If the noise margin is below the downshift noise margin (*RA-DSNRM*) and stays below that for more than the time specified by the minimum downshift rate adaptation interval (*RA-DTIME*), the VTU shall attempt to decrease the net data rate, such that the noise margin is increased to a level higher than or equal to the Downshift Noise Margin + 1 dB (see Figure 13-2).

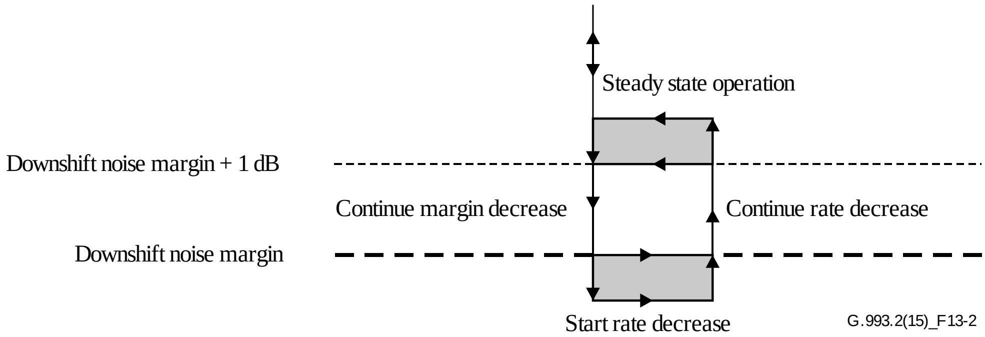

Figure 13-2 – SRA downshift procedure

If a *DVmax*$_p$ parameter specifies a bound on delay variation, it is possible that the rate decrease allowed by this maximum delay variation in a single SRA request is not sufficient to re-establish the margin to downshift noise margin + 1 dB. In this case, a number of consecutive SRA requests shall be executed until the margin is higher than or equal to the downshift noise margin + 1 dB.

13.4.2 Receiver initiated SRA upshift procedure

If the noise margin is above the upshift noise margin (*RA-USNRM*) and stays above that for more than the time specified by the minimum upshift rate adaptation interval (*RA-UTIME*), the VTU shall attempt to increase the net data rate, such that the noise margin is decreased to a level lower than or equal to the upshift noise margin –1 dB (see Figure 13-3).

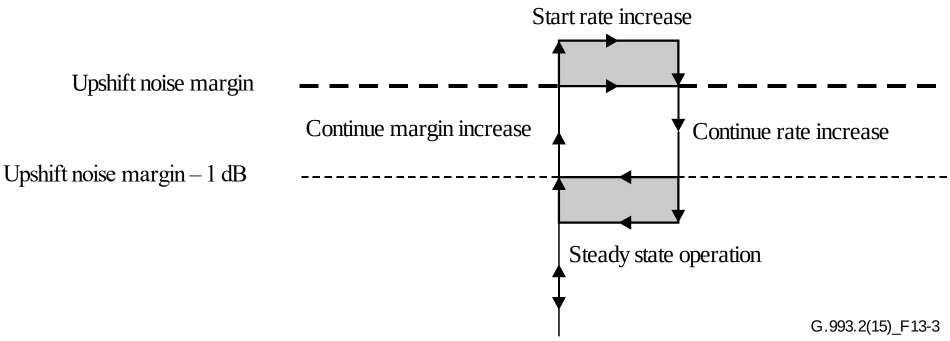

Figure 13-3 – SRA upshift procedure

If a *DVmax*$_p$ parameter specifies a bound on delay variation, it is possible that the rate increase allowed by this maximum delay variation in a single SRA request, is not sufficient to re-establish the margin to upshift noise margin –1 dB. In this case, a number of consecutive SRA requests shall be executed until the margin is lower than or equal to the upshift noise margin –1 dB.

13.4.3 Receiver initiated SOS

13.4.3.1 SOS triggering parameters

For each direction, three SOS triggering parameters are defined to support the standard SOS triggering criteria defined in clause 13.4.3.2.

13.4.3.1.1 SOS time Window (SOS-TIME)

The special value zero indicates that the standard SOS triggering criteria are disabled, i.e., vendor discretionary values may be used instead of the values configured in the MIB for the following parameters: SOS-NTONES, SOS-CRC, and SOS-TIME.

A non-zero value indicates that the standard SOS triggering criteria are enabled. In this case, SOS-TIME is the duration of the time window used in the standard SOS triggering criteria (see clause 13.4.3.2). This time window shall be applied to sequential time steps (i.e., not a sliding window).

The SOS-TIME defined for the downstream and upstream are denoted as SOS-TIME-ds and SOS-TIME-us, respectively.

13.4.3.1.2 Minimum Percentage of Degraded Tones (SOS-NTONES)

SOS-NTONES is the minimum percentage of loaded tones (i.e., tones with b_i>0) that must be persistently degraded throughout the time window SOS-TIME, in order to arm the first subcondition of the standard SOS triggering criteria (see clause 13.4.3.2).

A degraded tone is a tone that has been identified as needing a reduction in bit loading because, with its current bit loading, it contributes substantially to the increase of the BER above the nominal value. The degraded tones are not necessarily contiguous.

The SOS-NTONES defined for the downstream and upstream are denoted as SOS-NTONES-ds and SOS-NTONES-us, respectively.

13.4.3.1.3 Minimum Number of normalized CRC anomalies (SOS-CRC)

SOS-CRC is the minimum number of normalized CRC anomalies received in SOS-TIME seconds, in order to arm the second subcondition of the standard SOS triggering criteria (see clause 13.4.3.2).

The "count of normalized CRC anomalies" shall be incremented by the ΔCRCsecp (the one-second normalized CRC anomaly counter increment, as defined in Table 9-8 of this Recommendation) for each occurrence of a crc-p anomaly.

The SOS-CRC defined for the downstream and upstream are denoted as SOS-CRC-ds and SOS-CRC-us, respectively.

13.4.3.2 Standard SOS triggering criteria

If the following conditions hold:

- the standard SOS triggering criteria are enabled (through SOS-TIME ≠ 0);
- the percentage of tones in the MEDLEY SET that are persistently degraded throughout the time window SOS-TIME exceeds SOS-NTONES; and
- the count of normalized CRC anomalies throughout the same time window SOS-TIME exceeds SOS-CRC.

then the VTU:

- shall send either an SOS request or an SRA request if the number of degraded tones is ≤ 128 and the message length of the SRA request has a duration less than 100 ms; or
- shall send an SOS request if the number of degraded tones > 128 or if the message length of the SRA request has a duration more than 100 ms.

These SRA requests are not required to respect either RA-TIME or RA-SNRM.

The time between the moment that the SOS trigger conditions have become valid, and the SOS request or SRA request sent by the VTU appears at the U-interface, shall be less than 128 ms if there is no other outstanding OLR request.

If the standard SOS triggering criteria are disabled (through SOS-TIME = 0), the VTU may send SOS requests or SRA requests based on vendor-discretionary SOS triggering criteria. After each successful SOS, or SRA based on SOS triggering criteria, the count of normalized CRC anomalies shall be reset and a new time window shall be started.

13.4.3.3 Generic requirements for receiver initiated SOS

The VTU shall not send an SOS request if SOS is disabled (RA-MODE ≠ 4).

In the case the SOS results in a PER_p value outside the bounds given in Table 9-8, the VTU that initiated the SOS request shall send a subsequent SRA request within 1 second to bring the PER_p back within these bounds.

In the case the SOS results in an msg_p value outside the bounds given in Table 9-8, the VTU that initiated the SOS request shall send a subsequent SRA request within 1 second to bring the msg_p back within these bounds.

13.4.4 Receiver Initiated SRA following an SOS procedure

A VTU shall send one or more SRA requests following an SOS procedure to remediate the situation in which the current rate is less than Minimum Net Data Rate, or the actual noise margin is greater than the target noise margin. As long as the current bit rate is less than Minimum Net Data Rate, or the actual noise margin is greater than the target noise margin, these SRA requests are not required to respect either RA-UTIME or RA-USNRM.

NOTE – Although these SRA requests can be issued at the discretion of the VTU, the Note in clause 13.1 defines a goal for the overall duration of the SOS procedure.

14 Electrical requirements

14.1 Termination impedance model

The termination impedance model is for further study.

NOTE – The reference impedance model is intended to be used for splitter testing only, and is not intended to imply requirements on the values of the input impedance to be implemented in the transceiver.

14.2 Service splitters

For further study.

14.3 Input capacitance

Input capacitance requirements are shown in Table 14-1.

Table 14-1 – Input capacitance requirements

Underlying service			**Min capacitance (nF)**	**Max capacitance (nF)**
POTS	Integrated HPF	With US0	20	34
		Without US0	For further study	34
	External HPF	With US0	30	78
		Without US0	For further study	78
ISDN	Integrated HPF	With US0	6	11
		Without US0	For further study	11
	External HPF	With US0	10.8	59
		Without US0	For further study	59
No underlying service	N/A	N/A	No requirement	No requirement
NOTE – Capacitance shall be measured at a single frequency ≤ 4 kHz for over POTS and ≤ 30 kHz for over ISDN.				

Annex A

Region A (North America)

(This annex forms an integral part of this Recommendation.)

A.1 Band plan

The band plan for North America is shown in Figures A.1 and A.1.1. The US0 band, if present, has a lower frequency, f_{0L}, which can vary from 4 kHz (without POTS) to 25 kHz (with POTS), and an upper frequency, f_{0H}, which can vary from 138 to 276 kHz.

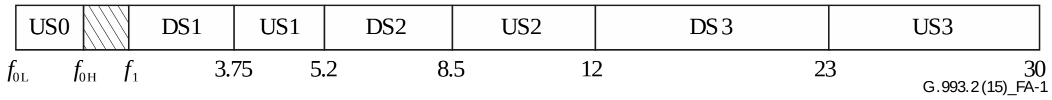

Figure A.1 – Band plan 998-30 for North America

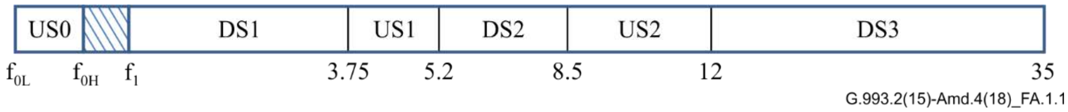

Figure A.1.1 – Band plan 998-35b for North America

NOTE – Deployments for these two band plans are not spectrally compatible over 23 MHz.

A.2 Limit PSD masks

The breakpoint frequencies and PSD values in Tables A.1 through A.8 are exact. The indicated slopes shown in corresponding Figures A.2 through A.6 are approximate.

NOTE 1 – The out-of-band specification above 1.1 MHz is governed by the stopband specification in Table 7-2.

NOTE 2 – It is expected that methods to verify compliance to the Limit PSD mask will be defined by the regional bodies.

A.2.1 VTU-R Limit PSD masks

The Limit PSD mask between the breakpoints is determined using the following interpolation rules:

- For frequencies less than (3 750 – 175) kHz, the breakpoints in Tables A.1 through A.8 shall be connected linearly on a plot with the abscissa $\log_{10}(f)$ and the ordinate the Limit PSD mask in dBm/Hz;
- For frequencies above (3 750 – 175) kHz, the breakpoints in Tables A.1 through A.8 shall be connected linearly on a plot with the abscissa f and the ordinate the Limit PSD mask in dBm/Hz.

A.2.1.1 VTU-R operation over POTS

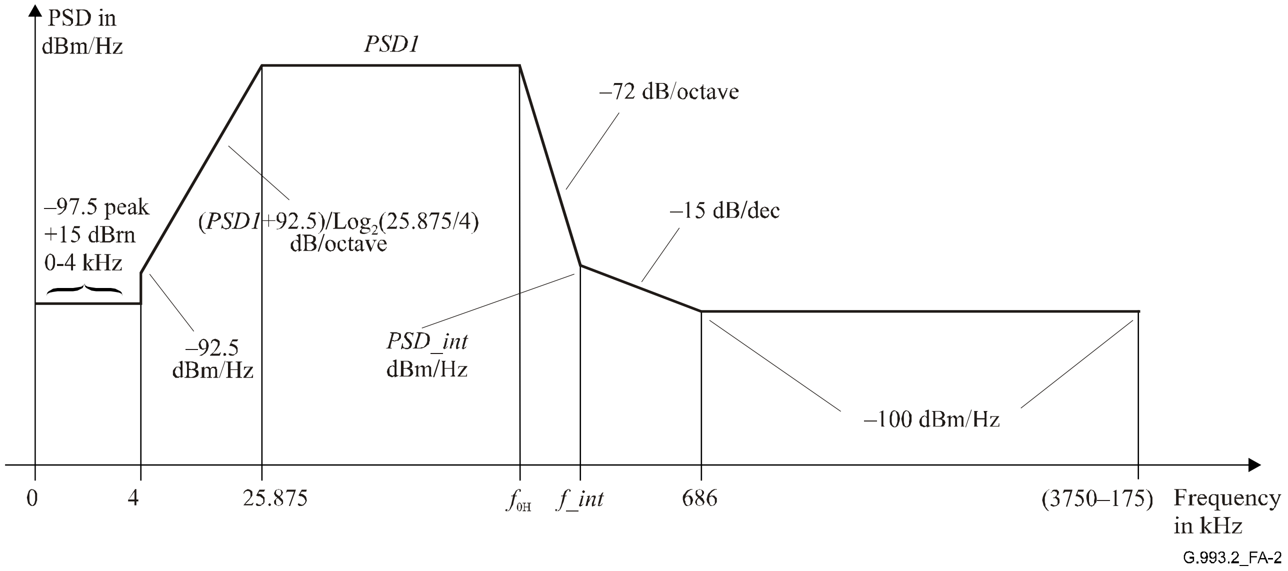

Figure A.2 – VTU-R US0 Limit PSD mask for operation over POTS

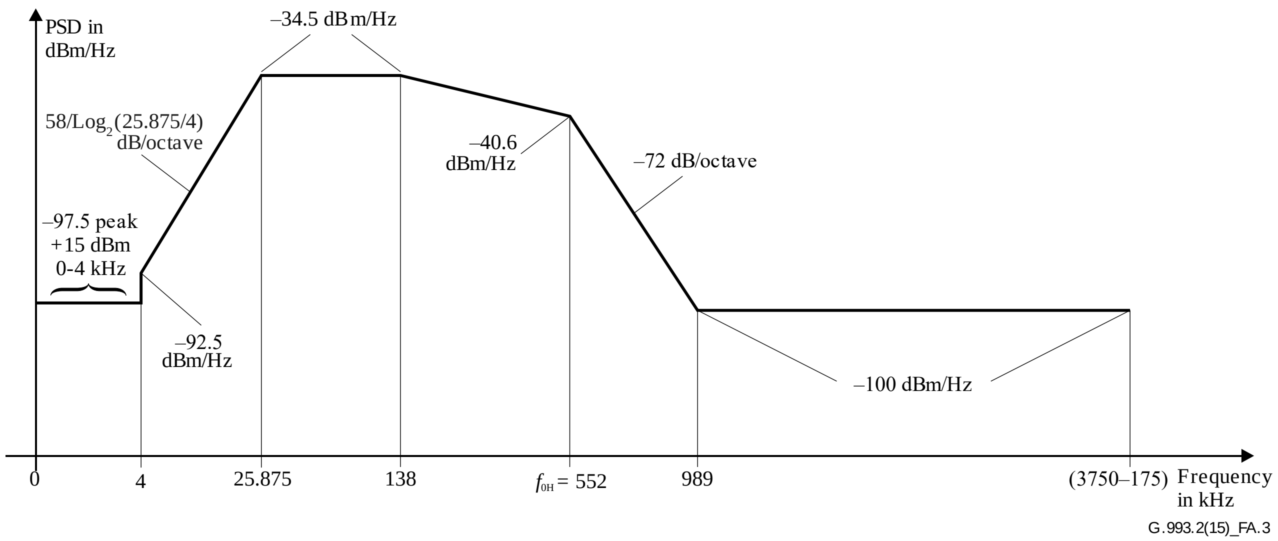

Figure A.3 – VTU-R EU-128 Limit PSD mask for operation over POTS

Table A.1 – VTU-R Limit PSD mask for operation over POTS as a function of profile

Frequency (kHz)	Limit PSD mask level (dBm/Hz) for profiles 8a, 8b, 8c, 8d	Limit PSD mask level (dBm/Hz) for profiles 12a, 12b, 17a	Limit PSD mask level (dBm/Hz) for profile 30a	Limit PSD mask level (dBm/Hz) for profile 35b
0	−97.5	−97.5	−97.5	−97.5
4	−97.5	−97.5	−97.5	−97.5
4	−92.5	−92.5	−92.5	−92.5
25.875	*PSD1* (see Table A.2)	*PSD1*	*PSD1* (see Table A.2)	PSD1 (see Table A.2)
f_{0H}	*PSD1* (see Table A.2)	*PSD1*	*PSD1* (see Table A.2)	PSD1 (see Table A.2)

Table A.1 – VTU-R Limit PSD mask for operation over POTS as a function of profile

Frequency (kHz)	Limit PSD mask level (dBm/Hz) for profiles 8a, 8b, 8c, 8d	Limit PSD mask level (dBm/Hz) for profiles 12a, 12b, 17a	Limit PSD mask level (dBm/Hz) for profile 30a	Limit PSD mask level (dBm/Hz) for profile 35b
f_int	*PSD_int* (see Table A.2)	*PSD_int*	*PSD_int* (see Table A.2)	*PSD_int* (see Table A.2)
686	−100	−100	−100	−100
1 104	−100	−100	−100	−100
3 750 – 175	−100	−100	−100	−100
3 750	−80	−80	−80	−80
3 750	−53 + 3.5	−53 + 3.5	−53 + 3.5	−53 + 3.5
5 200	−53 + 3.5	−53 + 3.5	−53 + 3.5	−53 + 3.5
5 200	−80	−80	−80	−80
5 200 + 175	−100	−100	−100	−100
8 500 – 175	−100	−100	−100	−100
8 500	−100	−80	−80	−80
8 500	−100	−54 + 3.5	−54 + 3.5	−54 + 3.5
12 000	−100	−54 + 3.5	−54 + 3.5	−54 + 3.5
12 000	−100	−80	−80	−80
12 000 + 175	−100	−100	−100	−100
23 000 − 175	−100	−100	−100	−100
23 000	−100	−100	−80	−100
23 000	−100	−100	−60 + 3.5	−100
30 000	−100	−100	−60 + 3.5	−100
30 000	−110	−110	−80	−110
30 175	−110	−110	−110	−110
≥ 30 175	−110	−110	−110	−110

Table A.2 – *PSD1*, *PSD_int* and the frequencies f_{0H} and *f_int*

Upstream mask-number	Designator	PSD1 (dBm/Hz)	Frequency f_{0H} (kHz)	Intercept frequency *f_int* (kHz)	Intercept PSD level *PSD_int* (dBm/Hz)
1	EU-32	−34.5	138.00	242.92	−93.2
2	EU-36	−35.0	155.25	274.00	−94.0
3	EU-40	−35.5	172.50	305.16	−94.7
4	EU-44	−35.9	189.75	336.40	−95.4
5	EU-48	−36.3	207.00	367.69	−95.9
6	EU-52	−36.6	224.25	399.04	−96.5
7	EU-56	−36.9	241.50	430.45	−97.0

Table A.2 – *PSD1*, *PSD_int* and the frequencies f_{0H} and *f_int*

Upstream mask-number	Designator	PSD1 (dBm/Hz)	Frequency f_{0H} (kHz)	Intercept frequency *f_int* (kHz)	Intercept PSD level *PSD_int* (dBm/Hz)
8	EU-60	−37.2	258.75	461.90	−97.4
9	EU-64	−37.5	276.00	493.41	−97.9
NOTE – EU-32 through EU-64 shall not be used in conjunction with D-128.					

Table A.3 – VTU-R EU-128 Limit PSD mask for operation over POTS as a function of profile

Frequency (kHz)	Limit PSD mask level (dBm/Hz) for profiles 8a, 8b, 8c, 8d	Limit PSD mask level (dBm/Hz) for profiles 12a, 12b, 17a	Limit PSD mask level (dBm/Hz) for profile 30a	Limit PSD mask level (dBm/Hz) for profile 35b
0	−97.5	−97.5	−97.5	−97.5
4	−97.5	−97.5	−97.5	−97.5
4	−92.5	−92.5	−92.5	−92.5
25.875	−34.5	−34.5	−34.5	−34.5
138	−34.5	−34.5	−34.5	−34.5
f_{0H} = 552	$-34.5 - 10\times\log_{10}(f_{0H} - 3)/(138 - 3)$	$-34.5 - 10\times\log_{10}(f_{0H} - 3)/(138 - 3)$	$-34.5 - 10\times\log_{10}(f_{0H} - 3)/(138 - 3)$	$-34.5 - 10\times\log_{10}(f_{0H} - 3)/(138 - 3)$
989	−100	−100	−100	−100
1 104	−100	−100	−100	−100
3 750 − 175	−100	−100	−100	−100
3 750	−80	−80	−80	−80
3 750	−53 + 3.5	−53 + 3.5	−53 + 3.5	−53 + 3.5
5 200	−53 + 3.5	−53 + 3.5	−53 + 3.5	−53 + 3.5
5 200	−80	−80	−80	−80
5 200 + 175	−100	−100	−100	−100
8 500 − 175	−100	−100	−100	−100
8 500	−100	−80	−80	−80
8 500	−100	−54 + 3.5	−54 + 3.5	−54 + 3.5
12 000	−100	−54 + 3.5	−54 + 3.5	−54 + 3.5
12 000	−100	−80	−80	−80
12 000 + 175	−100	−100	−100	−100
23 000 − 175	−100	−100	−100	−100
23 000	−100	−100	−80	−100
23 000	−100	−100	−60 + 3.5	−100
30 000	−100	−100	−60 + 3.5	−100

Table A.3 – VTU-R EU-128 Limit PSD mask for operation over POTS as a function of profile

Frequency (kHz)	Limit PSD mask level (dBm/Hz) for profiles 8a, 8b, 8c, 8d	Limit PSD mask level (dBm/Hz) for profiles 12a, 12b, 17a	Limit PSD mask level (dBm/Hz) for profile 30a	Limit PSD mask level (dBm/Hz) for profile 35b
30 000	−110	−110	−80	−110
30 175	−110	−110	−110	−110
≥ 30 175	−110	−110	−110	−110

A.2.1.2 VTU-R All-digital mode operation

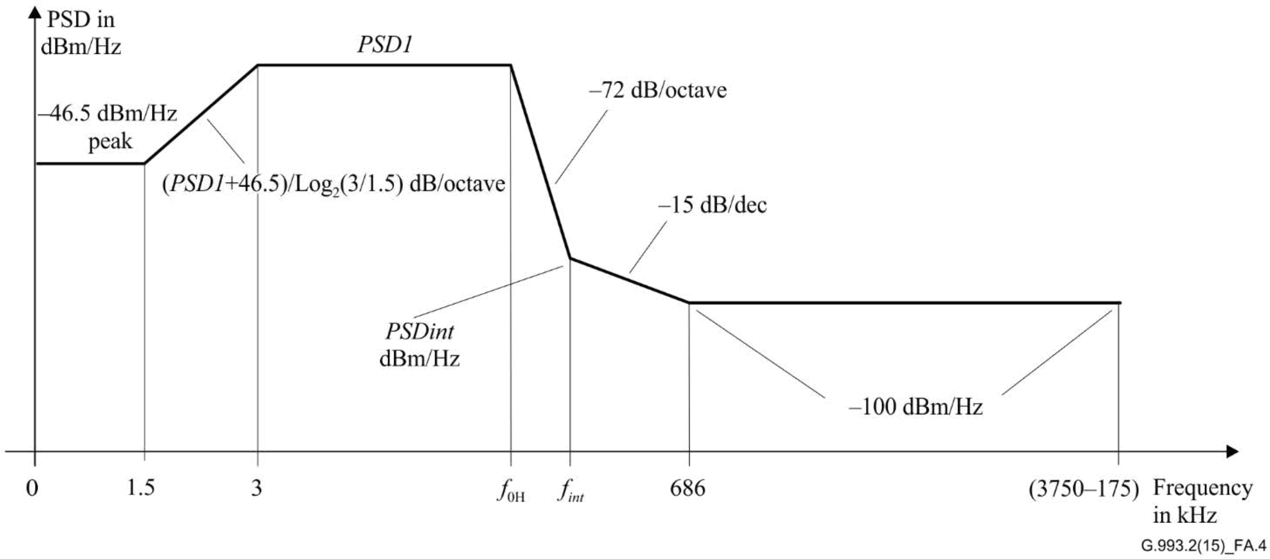

Figure A.4 – VTU-R US0 Limit PSD mask for all-digital mode operation

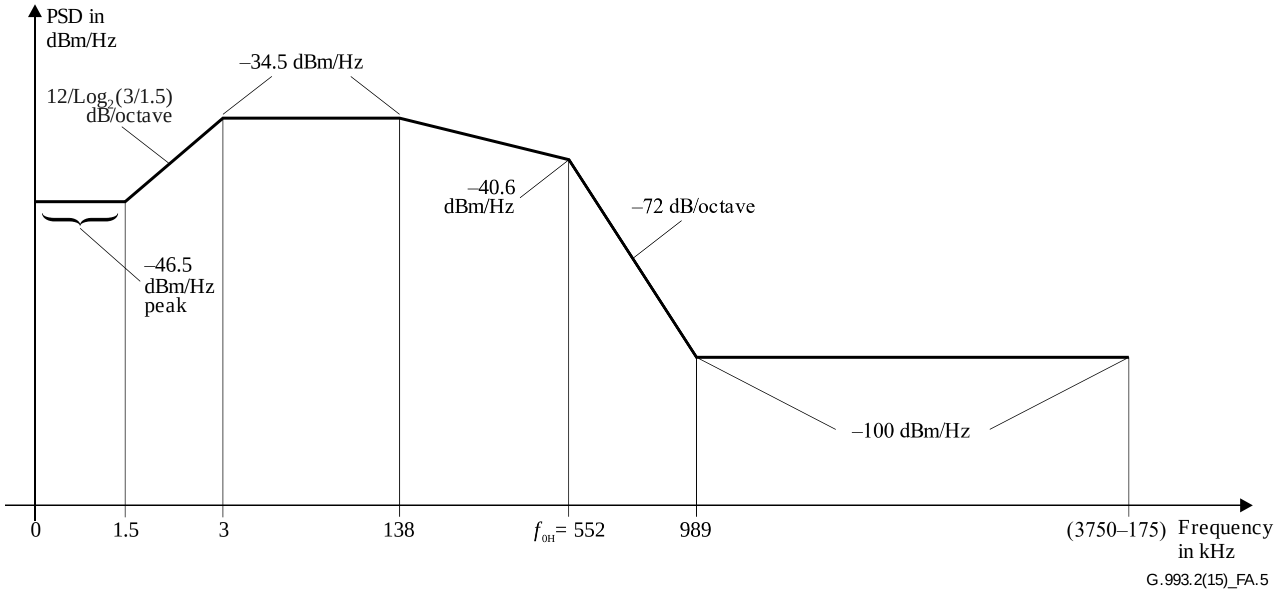

Figure A.5 – VTU-R ADLU-128 limit PSD mask for all-digital mode operation

Table A.4 – VTU-R limit PSD mask for all-digital mode operation as a function of profile

Frequency (kHz)	Limit PSD mask level (dBm/Hz) for profiles 8a, 8b, 8c, 8d	Limit PSD mask level (dBm/Hz) for profiles 12a, 12b, 17a	Limit PSD mask level (dBm/Hz) for profile 30a
0	−46.5	−46.5	−46.5
1.5	−46.5	−46.5	−46.5
3	*PSD1* (see Table A.5)	*PSD1*	*PSD1* (see Table A.5)
f_{0H}	*PSD1* (see Table A.5)	*PSD1*	*PSD1* (see Table A.5)
f_{int}	*PSDint* (see Table A.5)	*PSDint*	*PSDint* (see Table A.5)
686	−100	−100	−100
1 104	−100	−100	−100
3 750 − 175	−100	−100	−100
3 750	−80	−80	−80
3 750	−53 + 3.5	−53 + 3.5	−53 + 3.5
5 200	−53 + 3.5	−53 + 3.5	−53 + 3.5
5 200	−80	−80	−80
5 200 + 175	−100	−100	−100
8 500 − 175	−100	−100	−100
8 500	−100	−80	−80
8 500	−100	−54 + 3.5	−54 + 3.5
12 000	−100	−54 + 3.5	−54 + 3.5
12 000	−100	−80	−80
12 000 + 175	−100	−100	−100
23 000 − 175	−100	−100	−100
23 000	−100	−100	−80
23 000	−100	−100	−60 + 3.5
30 000	−100	−100	−60 + 3.5
30 000	−110	−110	−80
30 175	−110	−110	−110
≥ 30 175	−110	−110	−110

Table A.5 – *PSD*1, *PSDint* and the frequencies f_{0H} and f_{int}

Upstream mask-number	Designator	*PSD*1 (dBm/Hz)	Frequency f_{0H} (kHz)	Intercept frequency f_{int} (kHz)	Intercept PSD level *PSDint* (dBm/Hz)
1	ADLU-32	−34.5	138.00	242.92	−93.2
2	ADLU-36	−35.0	155.25	274.00	−94.0
3	ADLU-40	−35.5	172.50	305.16	−94.7
4	ADLU-44	−35.9	189.75	336.40	−95.4

Table A.5 – *PSD*1, *PSDint* and the frequencies f_{0H} and f_{int}

Upstream mask-number	Designator	*PSD*1 (dBm/Hz)	Frequency f_{0H} (kHz)	Intercept frequency f_{int} (kHz)	Intercept PSD level *PSDint* (dBm/Hz)
5	ADLU-48	−36.3	207.00	367.69	−95.9
6	ADLU-52	−36.6	224.25	399.04	−96.5
7	ADLU-56	−36.9	241.50	430.45	−97.0
8	ADLU-60	−37.2	258.75	461.90	−97.4
9	ADLU-64	−37.5	276.00	493.41	−97.9
NOTE – ADLU-32 through ADLU-64 shall not be used in conjunction with D-128.					

Table A.6 – VTU-R ADLU-128 Limit PSD mask for all-digital mode operation as a function of profile

Frequency (kHz)	Limit PSD mask level (dBm/Hz) for profiles 8a, 8b, 8c, 8d	Limit PSD mask level (dBm/Hz) for profiles 12a, 12b, 17a	Limit PSD mask level (dBm/Hz) for profile 30a
0	−46.5	−46.5	−46.5
1.5	−46.5	−46.5	−46.5
3	−34.5	−34.5	−34.5
138	−34.5	−34.5	−34.5
f_{0H} = 552	$-34.5 - 10\times\log_{10}(f_{0H} - 3)/(138 - 3)$	$-34.5 - 10\times\log_{10}(f_{0H} - 3)/(138 - 3)$	$-34.5 - 10\times\log_{10}(f_{0H} - 3)/(138 - 3)$
989	−100	−100	−100
1 104	−100	−100	−100
3 750 − 175	−100	−100	−100
3 750	−80	−80	−80
3 750	−53 + 3.5	−53 + 3.5	−53 + 3.5
5 200	−53 + 3.5	−53 + 3.5	−53 + 3.5
5 200	−80	−80	−80
5 200 + 175	−100	−100	−100
8 500 − 175	−100	−100	−100
8 500	−100	−80	−80
8 500	−100	−54 + 3.5	−54 + 3.5
12 000	−100	−54 + 3.5	−54 + 3.5
12 000	−100	−80	−80
12 000 + 175	−100	−100	−100
23 000 − 175	−100	−100	−100
23 000	−100	−100	−80
23 000	−100	−100	−60 + 3.5
30 000	−100	−100	−60 + 3.5

Table A.6 – VTU-R ADLU-128 Limit PSD mask for all-digital mode operation as a function of profile

Frequency (kHz)	Limit PSD mask level (dBm/Hz) for profiles 8a, 8b, 8c, 8d	Limit PSD mask level (dBm/Hz) for profiles 12a, 12b, 17a	Limit PSD mask level (dBm/Hz) for profile 30a
30 000	−110	−110	−80
30 175	−110	−110	−110
≥ 30 175	−110	−110	−110

NOTE – The actual transmit PSD shape is further constrained by the total power limit of 14.5 dBm as well as additional spectral compatibility rules imposed by regional authorities.

A.2.2 VTU-O Limit PSD masks

The Limit PSD mask between the breakpoints is determined using the following interpolation rules:

- For frequencies less than f_1, the breakpoints in Tables A.1 through A.8 shall be connected linearly on a plot with the abscissa $\log_{10}(f)$ and the ordinate the Limit PSD mask in dBm/Hz.
- For frequencies above f_1, the breakpoints in Tables A.1 through A.8 shall be connected linearly a plot with the abscissa f and the ordinate the Limit PSD mask in dBm/Hz.

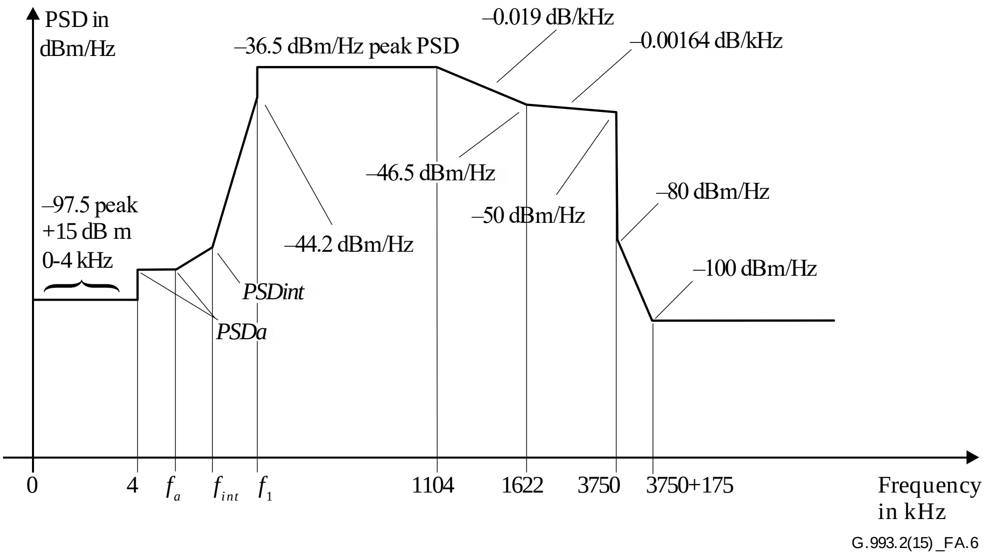

Figure A.6 – VTU-O DS1 limit PSD mask

Table A.7 – VTU-O Limit PSD mask as a function of profile

Frequency (kHz)	Limit PSD mask level (dBm/Hz) for profiles 8a, 8b, 8c, 8d, 12a and 12b	Limit PSD mask level (dBm/Hz) for profile 17a	Limit PSD mask level (dBm/Hz) for profile 30a	Limit PSD Mask level (dBm/Hz) for profile 35b
0	−97.5	−97.5	−97.5	−97.5
4	−97.5	−97.5	−97.5	−97.5
4	*PSDa* (see Table A.8)	*PSDa* (see Table A.8)	*PSDa* (see Table A.8)	*PSDa* (see Table A.8)

Table A.7 – VTU-O Limit PSD mask as a function of profile

Frequency (kHz)	Limit PSD mask level (dBm/Hz) for profiles 8a, 8b, 8c, 8d, 12a and 12b	Limit PSD mask level (dBm/Hz) for profile 17a	Limit PSD mask level (dBm/Hz) for profile 30a	Limit PSD Mask level (dBm/Hz) for profile 35b
f_a	*PSDa* (see Table A.8)	*PSDa* (see Table A.8)	*PSDa* (see Table A.8)	*PSDa* (see Table A.8)
f_{int}	*PSDint* (see Table A.8)	*PSDint* (see Table A.8)	*PSDint* (see Table A.8)	*PSDint* (see Table A.8)
f_1	−44.2	−44.2	−44.2	−44.2
f_1	−36.5	−36.5	−36.5	−36.5
1 104	−36.5	−36.5	−36.5	−36.5
1 622	−50 + 3.5	−50 + 3.5	−50 + 3.5	−50 + 3.5
3 750	−53.5 + 3.5	−53.5 + 3.5	−53.5 + 3.5	−53.5 + 3.5
3 750	−80	−80	−80	−80
3 750 + 175	−100	−100	−100	−100
5 200 − 175	−100	−100	−100	−100
5 200	−80	−80	−80	−80
5 200	−55 + 3.5	−55 + 3.5	−55 + 3.5	−55 + 3.5
8 500	−55 + 3.5	−55 + 3.5	−55 + 3.5	−55 + 3.5
8 500	−80	−80	−80	−80
8 500 + 175	−100	−100	−100	−100
12 000 − 175	−100	−100	−100	−100
12 000	−100	−80	−80	−80
12 000	−100	−60 + 3.5	−60 + 3.5	−60 + 3.5
17 664	−100	−60 + 3.5	−60 + 3.5	−60 + 3.5
21 000	−100	−80	−60 + 3.5	−60 + 3.5
21 450	−100	−100	−60 + 3.5	−60 + 3.5
23 000	−100	−100	−60 + 3.5	−60 + 3.5
23 000	−100	−100	−80	−60 + 3.5
23 000 + 175	−100	−100	−100	−60 + 3.5
30 000	−100	−100	−100	−60 + 3.5
30 000	−110	−110	−110	–73
35 328	−110	−110	−110	–73.4
37 000	−110	−110	−110	−83
40 656	−110	−110	−110	–110
> 40 656	−110	−110	−110	–110

Table A.8 – *PSD_int* and *PSDa* and the frequencies f_1, *f_int*, and f_a

Designator	f_1 **(kHz)**	f_{int} **(kHz)**	***PSDint*** **(dBm/Hz)**	f_a **(kHz)**	***PSDa*** **(dBm/Hz)**
D-32	138.00	80	−72.5	4	−92.5
D-48	207.00	155	−62	53	−90
D-64	276.00	227.1	−62	101.2	−90
D-128 (Note)	552.00	440	–68	240	–90
NOTE – D-128 shall only be used in conjunction with EU-128 or ADLU-128.					

A.3 UPBO reference PSDs

ATIS Committee NIPP has published a technical report [b-ATIS-0600023] that provides guidance on the configuration of the UPBO parameters 'a' and 'b' for the North American environment.

Annex B

Region B (Europe)

(This annex forms an integral part of this Recommendation.)

B.1 Band plans

This annex defines the various band plans required for European deployment of VDSL2 systems operating at a maximum frequency of 12, 17, 30 or 35 MHz. These are based on [ITU-T G.993.1] band plans A and B (also referred to as plan 998 and plan 997, respectively). The various band plans are defined in Table B.1 below and can be summarized as follows:

Plan 997 The original plan 997 (f_{max} = 12 MHz).

Plan 997E17 Plan 997 directly extended to f_{max} = 17.664 MHz.

Plan 997E30 Plan 997 directly extended to f_{max} = 30 MHz.

NOTE – Plan 997E17 and plan 997 are truncated versions of plan 997E30.

Plan 998 The original plan 998 (f_{max} = 12 MHz).

Plan 998E17 Plan 998 directly extended to f_{max} = 17.664 MHz.

Plan 998E30 Plan 998 directly extended to f_{max} = 30 MHz.

NOTE – Plan 998E17 and plan 998 are truncated versions of plan 998E30.

Plan 998E35 Plan 998 directly extended to f_{max} = 35.328 MHz (frequencies above 14 MHz are for downstream transmission only).

NOTE – Plan 998E17 and plan 998 are truncated versions of plan 998E30 and plan 998E35.

Plan 998ADE17 Plan 998 extended to f_{max} = 17.664 MHz (downstream transmission only above 12 MHz)

Plan 998ADE30 Plan 998 extended to f_{max} = 30 MHz.

Plan 998ADE35 Plan 998 extended to f_{max} = 35.328 MHz (frequencies above 12 MHz are for downstream transmission only).

NOTE – Plan 998ADE17 and plan 998 are truncated versions of plan 998ADE30 and plan 998ADE35.

Different variants are defined for band plans 997, 998, 998E17, 998E30, 998E35, 998ADE17, 998ADE30 and 998ADE35 to accommodate different underlying services (POTS and ISDN), and different US0 bandwidths.

Table B.1 – Band-edge frequencies for European VDSL2 band plans

Band plan	Band-edge frequencies (as defined in the generic band plan in clause 7.1.2)										
	f_{0L} kHz	f_{0H} kHz	f_1 kHz	f_2 kHz	f_3 kHz	f_4 kHz	f_5 kHz	f_6 kHz	f_7 kHz	f_8 kHz	f_9 kHz
	US0		DS1	US1	DS2	US2	DS3	US3	DS4	US4	
997	25	138	138	3 000	5 100	7 050	12 000	N/A	N/A	N/A	N/A
	25	276	276								
997E17	25	138	138	3 000	5 100	7 050	12 000	14 000	17 664	N/A	N/A
997E30	N/A	N/A	138	3 000	5 100	7 050	12 000	14 000	19 500	27 000	30 000
	US0		DS1	US1	DS2	US2	US3	DS3	US4	DS4	
998	25	138	138	3 750	5 200	8 500	12 000	N/A	N/A	N/A	N/A
	25	276	276								
	120	276	276								
	N/A	N/A	138								
998E17	N/A	N/A	138	3 750	5 200	8 500	12 000	14 000	17 664	N/A	N/A
	N/A	N/A	276								
	25	138	138								
998E30	N/A	N/A	138	3 750	5 200	8 500	12 000	14 000	21 450	24 890	30 000
	N/A	N/A	276								
998E35	25	138	138	3 750	5 200	8500	12 000	14 000	35 328	N/A	N/A
	US0		DS1	US1	DS2	US2	DS3	US3			
998ADE17	25	138	138	3 750	5 200	8 500	12 000	17 664	N/A		
	120	276	276								
	25	276	276								

Table B.1 – Band-edge frequencies for European VDSL2 band plans

Band plan	Band-edge frequencies (as defined in the generic band plan in clause 7.1.2)										
	f_{0L} kHz	f_{0H} kHz	f_1 kHz	f_2 kHz	f_3 kHz	f_4 kHz	f_5 kHz	f_6 kHz	f_7 kHz	f_8 kHz	f_9 kHz
	N/A	N/A	276								
998ADE30	N/A	N/A	138	3 750	5 200	8 500	12 000	24 890	30 000		
	N/A	N/A	276								
998ADE35	25	138	138	3 750	5 200	8 500	12 000	35 328	N/A		
	120	276	276								
	25	276	276								

NOTE 1 – N/A in the columns f_{0L} and f_{0H} designates a band plan variant that does not use US0.
NOTE 2 – The capability to support US0 together with profile 17a is required for European VDSL2.
NOTE 3 – The capability to support US0 together with profile 35b is required for European VDSL2.

The f_i in Table B.1 are defined as follows:

- f_{0L} and f_{0H}: define lower and upper frequency of US0;
- f_1 to f_5 are the boundary frequencies of the bands DS1, US1, DS2, US2 as defined for VDSL1 for 997 and 998;
- f_5 to f_9 are the boundary frequencies for the bands US3, DS3, US4 and DS4 (extended bands);
- The extension of an existing band is considered as a separate band (e.g., 998E17: US3 12 MHz-14 MHz).

B.2 Limit PSD mask options

The Limit PSD mask options defined in this annex are shown in Tables B.2, B.3 and B.4, for various band plans.

Table B.2 – European Limit PSD mask options for band plan 997 (and its extensions)

Short name	Limit PSD mask (Long name)	Frequency	
		US0 type A/M (Note)	Highest used upstream or downstream frequency (kHz)
B7-1	997-M1c-A-7	A	7 050
B7-3	997-M1x-M	M	12 000
B7-9	997E17-M2x-A	A	17 664
B7-10	997E30-M2x-NUS0	N/A	30 000

NOTE – The US0 types stand for:
- US0 type A corresponds to Annex A of [ITU-T G.992.5];
- US0 type M corresponds to Annex M of [ITU-T G.992.3] or of [ITU-T G.992.5];
- US0 type N/A designates a band plan variant that does not use US0.

Table B.3 – European limit PSD mask options for band plan 998 (and its extensions)

Short name	Limit PSD mask (Long name)	Frequency	
		US0 type A/B/M (Note)	Highest used upstream or downstream frequency (kHz)
B8-4	998-M2x-A	A	12 000
B8-5	998-M2x-M	M	12 000
B8-6	998-M2x-B	B	12 000
B8-7	998-M2x-NUS0	N/A	12 000
B8-8	998E17-M2x-NUS0	N/A	17 664
B8-9	998E17-M2x-NUS0-M	N/A	17 664
B8-10	998ADE17-M2x-NUS0-M	N/A	17 664
B8-11	998ADE17-M2x-A	A	17 664
B8-12	998ADE17-M2x-B	B	17 664
B8-13	998E30-M2x-NUS0	N/A	30 000
B8-14	998E30-M2x-NUS0-M	N/A	30 000
B8-15	998ADE30-M2x-NUS0-M	N/A	30 000
B8-16	998ADE30-M2x-NUS0-A	N/A	30 000
B8-17	998ADE17-M2x-M	M	17 664
B8-18	998E17-M2x-A	A	17 664

Table B.3 – European limit PSD mask options for band plan 998 (and its extensions)

Short name	Limit PSD mask (Long name)	Frequency	
		US0 type A/B/M (Note)	Highest used upstream or downstream frequency (kHz)
B8-19	998E35-M2x-A	A	35 328
B8-20	998ADE35-M2x-A	A	35 328
B8-21	998ADE35-M2x-B	B	35 328
B8-22	998ADE35-M2x-M	M	35 328

NOTE – The US0 types stand for:

- US0 type A corresponds to Annex A of [ITU-T G.992.5];
- US0 type B corresponds to Annex B of [ITU-T G.992.5];
- US0 type M corresponds to Annex M of [ITU-T G.992.3] or of [ITU-T G.992.5];
- US0 type N/A designates a band plan variant that does not use US0;
- 998ADExx-M2x-NUS0-M designate the variants in which DS1 starts at 276 kHz instead of 138 kHz.

B.2.1 General requirements in the band below 4 kHz

The noise in the voice band measured with psophometric weighting according to [ITU-T O.41] clause 3.3 shall not exceed –68 dBm. The psophometer shall be used in bridging mode and shall be calibrated for 600-ohm termination.

B.2.2 VTU-R Limit PSD masks for band plan 997 (and its extensions)

The VTU-R limit PSD masks for band plan 997 (and its extensions) are shown in Table B.4.

Table B.4 – VTU-R limit PSD masks for band plan 997 (and its extensions)

Name	**B7-1**	**B7-3**	**B7-9**	**B7-10**
Long name	**997-M1-c-A-7**	**997-M1-x-M**	**997E17-M2x-A**	**997E30-M2x-NUS0**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
0	–97.5	–97.5	–97.5	–100
4	–97.5	–97.5	–97.5	–100
4	–92.5	–92.5	–97.5	–100
25.875	–34.5	–37.5	–34.5	–100
50	–34.5	–37.5	–34.5	–100
80	–34.5	–37.5	–34.5	–100
120	–34.5	–37.5	–34.5	–100
138	–34.5	–37.5	–34.5	–100
225	Interp	–37.5	Interp	–100
243	−93.2	–37.5	–93.2	–100
276	Interp	–37.5	Interp	–100
493.41	Interp	–97.9	Interp	–100
686	–100	–100	–100	–100
2 825	–100	–100	–100	–100
3 000	–80	–80	–80	–80
3 000	–56.5	–56.5	–50.3	–50.3
3 575	–56.5	–56.5	Interp	Interp
3 750	–56.5	–56.5	Interp	Interp
5 100	–56.5	–56.5	–52.6	–52.6
5 100	–80	–80	–80	–80
5 275	–100	–100	–100	–100
6 875	–100	–100	–100	–100
7 050	–100	–80	–80	–80
7 050	–100	–56.5	–54	–54
8 325	–100	–56.5	Interp	Interp
9 950	–100	–56.5	Interp	Interp
10 125	–100	–56.5	–55.5	–55.5
10 125	–100	–56.5	–55.5	–55.5
11 825	–100	–56.5	–55.5	–55.5
12 000	–100	–56.5	–55.5	–55.5
12 000	–100	–80	–80	–80
12 175	–100	–100	–100	–100
13 825	–100	–100	–100	–100
14 000	–100	–100	–80	–80

Table B.4 – VTU-R limit PSD masks for band plan 997 (and its extensions)

Name	B7-1	B7-3	B7-9	B7-10
Long name	997-M1-c-A-7	997-M1-x-M	997E17-M2x-A	997E30-M2x-NUS0
kHz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz
14 000	–100	–100	–56.5	–56.5
14 175	–100	–100	Interp	Interp
17 664	–100	–100	–56.5	–56.5
19 500	–100	–100	–80	–56.5
19 500	–100	–100	–80	–80
19 675	–100	–100	–100	–100
21 275	–100	–100	–100	–100
21 450	–100	–100	–100	–100
21 450	–100	–100	–100	–100
24 890	–100	–100	–100	–100
24 890	–100	–100	–100	–100
25 065	–100	–100	–100	–100
26 825	–100	–100	–100	–100
27 000	–100	–100	–100	–80
27 000	–100	–100	–100	–56.5
30 000	–100	–100	–100	–56.5
30 000	-110	-110	-110	–80
30 175	-110	-110	-110	-110
> 30 175	–110	–110	–110	–110

NOTE – The PSD values between breakpoints including the values marked by "Interp" shall be obtained by interpolation between adjacent breakpoints as follows:
- below 2 825 kHz on a dB/log(*f*) basis; and
- above 2 825 kHz on a dB/*f* basis.

B.2.3 VTU-O Limit PSD masks for band plans 997 (and its extensions)

The VTU-O limit PSD masks for band plan 997 (and its extensions) are shown in Table B.5.

Table B.5 – VTU-O Limit PSD masks for band plan 997 (and its extensions)

Name	B7-1	B7-3	B7-9	B7-10
Long name	997-M1c-A-7	997-M1x-M	997E17-M2x-A	997E30-M2x-NUS0
kHz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz
0	–97.5	–97.5	–97.5	–97.5
4	–97.5	–97.5	–97.5	–97.5
4	–92.5	–92.5	–92.5	–92.5
80	–72.5	–92.5	–72.5	–72.5

Table B.5 – VTU-O Limit PSD masks for band plan 997 (and its extensions)

Name	B7-1	B7-3	B7-9	B7-10
Long name	**997-M1c-A-7**	**997-M1x-M**	**997E17-M2x-A**	**997E30-M2x-NUS0**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
101.2	Interp	–92.5	Interp	Interp
138	–49.5	Interp	–44.2	–44.2
138	–49.5	Interp	–36.5	–36.5
227.11	–49.5	–62	–36.5	–36.5
276	–49.5	–48.5	–36.5	–36.5
276	–49.5	–36.5	–36.5	–36.5
1 104	–49.5	–36.5	–36.5	–36.5
1 622	–49.5	–46.5	–46.5	–46.5
2 208	–49.5	–48	Interp	Interp
2 236	–49.5	Interp	Interp	Interp
2 249	–49.5	–49.5	Interp	Interp
2 423	–56.5	Interp	Interp	Interp
2 500	–56.5	–56.5	Interp	Interp
3 000	–56.5	–56.5	–49.6	–49.6
3 000	–80	–80	–80	–80
3 175	–100	–100	–100	–100
4 925	–100	–100	–100	–100
5 100	–80	–80	–80	–80
5 100	–56.5	–56.5	–52.6	–52.6
5 200	–56.5	–56.5	Interp	Interp
6 875	–56.5	–56.5	Interp	Interp
7 050	–56.5	–56.5	–54	–54
7 050	–80	–80	–80	–80
7 225	–100	–100	–100	–100
10 125	–100	–100	–100	–100
10 125	–100	–100	–100	–100
10 300	–100	–100	–100	–100
11 825	–100	–100	–100	–100
12 000	–100	–100	–80	–80
12 000	–100	–100	–56.5	–56.5
13 825	–100	–100	–56.5	–56.5
14 000	–100	–100	–56.5	–56.5
14 000	–100	–100	–80	–80
14 175	–100	–100	–100	–100
17 489	-100	-100	-100	–100
17 664	–100	–100	–100	–100
17 664	–100	–100	–100	–100

Table B.5 – VTU-O Limit PSD masks for band plan 997 (and its extensions)

Name	**B7-1**	**B7-3**	**B7-9**	**B7-10**
Long name	**997-M1c-A-7**	**997-M1x-M**	**997E17-M2x-A**	**997E30-M2x-NUS0**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
19 325	–100	–100	–100	–100
19 500	–100	–100	–100	–80
19 500	–100	–100	–100	–56.5
21 000	–100	–100	–100	–56.5
21 450	–100	–100	–100	–56.5
21 450	–100	–100	–100	–56.5
21 625	–100	–100	–100	–56.5
24 715	–100	–100	–100	–56.5
24 890	–100	–100	–100	–56.5
24 890	–100	–100	–100	–56.5
27 000	–100	–100	–100	–56.5
27 000	–100	–100	–100	–80
27 175	–100	–100	–100	–100
30 000	–100	–100	–100	–100
30 000	–110	–110	–110	–110
30 175	–110	–110	–110	–110
> 30 175	–110	–110	–110	–110

NOTE – The PSD values between breakpoints including the values marked by "Interp" shall be obtained by interpolation between adjacent breakpoints as follows:

– below f_1 on a dB/log(f) basis; and
– above f_1 on a dB/f basis.

B.2.4 VTU-R limit PSD masks for band plan 998 (and its extensions)

The VTU-R limit PSD masks for band plan 998 (and its extensions) with a highest used upstream or downstream frequency of 12 MHz or 17.664 MHz (see Table B.3 for the band plan 998 PSD mask options) are shown in Table B.6A.

Table B.6A – VTU-R limit PSD masks for band plan 998 (and its extensions) with a highest used frequency of 12 MHz or 17.664 MHz

Name	B8-4	B8-5	B8-6	B8-7	B8-8	B8-9	B8-10	B8-11	B8-12	B8-17	B8-18
Long name	998-M2x-A	998-M2x-M	998-M2x-B	998-M2x-NUS0	998 E17-M2x-NUS0	998 E17-M2x-NUS0-M	998 ADE17-M2x-NUS0-M	998 ADE17-M2x-A	998 ADE17-M2x-B	998 ADE17-M2x-M	998 E17-M2x-A
kHz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz
0	–97.5	–97.5	–97.5	–100	–100	–100	–100	–97.5	–97.5	–97.5	–97.5
4	–97.5	–97.5	–97.5	–100	–100	–100	–100	–97.5	–97.5	–97.5	–97.5
4	–92.5	–92.5	–92.5	–100	–100	–100	–100	–92.5	–92.5	–92.5	–92.5
25.875	–34.5	–37.5	–92.5	–100	–100	–100	–100	–34.5	–92.5	–37.5	–34.5
50	–34.5	–37.5	–90	–100	–100	–100	–100	–34.5	–90	–37.5	–34.5
80	–34.5	–37.5	–81.8	–100	–100	–100	–100	–34.5	–81.8	–37.5	–34.5
120	–34.5	–37.5	–34.5	–100	–100	–100	–100	–34.5	–34.5	–37.5	–34.5
138	–34.5	–37.5	–34.5	–100	–100	–100	–100	–34.5	–34.5	–37.5	–34.5
225	Interp	–37.5	–34.5	–100	–100	–100	–100	Interp	–34.5	–37.5	Interp
243	–93.2	–37.5	–34.5	–100	–100	–100	–100	–93.2	–34.5	–37.5	–93.2
276	Interp	–37.5	–34.5	–100	–100	–100	–100	Interp	–34.5	–37.5	Interp
493.41	Interp	–97.9	Interp	–100	–100	–100	–100	Interp	Interp	–97.9	Interp
508.8	Interp	Interp	–98	–100	–100	–100	–100	Interp	–98	Interp	Interp
686	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
3 575	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
3 750	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80
3 750	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2
5 200	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7

Table B.6A – VTU-R limit PSD masks for band plan 998 (and its extensions) with a highest used frequency of 12 MHz or 17.664 MHz

Name	B8-4	B8-5	B8-6	B8-7	B8-8	B8-9	B8-10	B8-11	B8-12	B8-17	B8-18
Long name	**998-M2x-A**	**998-M2x-M**	**998-M2x-B**	**998-M2x-NUS0**	**998 E17-M2x-NUS0**	**998 E17-M2x-NUS0-M**	**998 ADE17-M2x-NUS0-M**	**998 ADE17-M2x-A**	**998 ADE17-M2x-B**	**998 ADE17-M2x-M**	**998 E17-M2x-A**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
5 200	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80
5 375	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
8 325	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
8 500	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80
8 500	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8
10 000	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5
12 000	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5
12 000	–80	–80	–80	–80	–56.5	–56.5	–80	–80	–80	–80	–56.5
12 175	–100	–100	–100	–100	–56.5	–56.5	–100	–100	–100	–100	–56.5
14 000	–100	–100	–100	–100	–56.5	–56.5	–100	–100	–100	–100	–56.5
14 000	–100	–100	–100	–100	–80	–80	–100	–100	–100	–100	–80
14 175	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
21 275	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
30 000	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
30 000	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110
30 175	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110
> 30 175	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110

NOTE – The PSD values between breakpoints including the values marked by "Interp" shall be obtained by interpolation between adjacent breakpoints as follows:

– below 3 575 kHz on a dB/log(*f*) basis; and
– above 3 575 kHz on a dB/*f* basis.

The VTU-R limit PSD masks for band plan 998 (and its extensions) with a highest used upstream or downstream frequency of 30 MHz or 35.328 MHz (see Table B.3 for the band plan 998 PSD mask options) are shown in Table B.6B.

Table B.6B – VTU-R limit PSD masks for band plan 998 (and its extensions) with highest used frequency of 30 MHz or 35.328 MHz

Name	**B8-13**	**B8-14**	**B8-15**	**B8-16**	**B8-19**	**B8-20**	**B8-21**	**B8-22**
Long name	**998 E30- M2x- NUS0**	**998 E30- M2x- NUS0-M**	**998 ADE30- M2x- NUS0-M**	**998 ADE30- M2x- NUS0-A**	**998 E35- M2x-A**	**998 ADE35- M2x-A**	**998 ADE35- M2x-B**	**998 ADE35- M2x-M**
kHz	**dBm/ Hz**	**dBm/ Hz**	**dBm/ Hz**	**dBm/ Hz**	**dBm/ Hz**	**dBm/ Hz**	**dBm/ Hz**	**dBm/ Hz**
0	–100	–100	–100	–100	–97.5	–97.5	–97.5	–97.5
4	–100	–100	–100	–100	–97.5	–97.5	–97.5	–97.5
4	–100	–100	–100	–100	–92.5	–92.5	–92.5	–92.5
25.875	–100	–100	–100	–100	–34.5	–34.5	–92.5	–37.5
50	–100	–100	–100	–100	–34.5	–34.5	–90	–37.5
80	–100	–100	–100	–100	–34.5	–34.5	–81.8	–37.5
120	–100	–100	–100	–100	–34.5	–34.5	–34.5	–37.5
138	–100	–100	–100	–100	–34.5	–34.5	–34.5	–37.5
225	–100	–100	–100	–100	Interp	Interp	–34.5	–37.5
243	–100	–100	–100	–100	–93.2	–93.2	–34.5	–37.5
276	–100	–100	–100	–100	Interp	Interp	–34.5	–37.5
493.41	–100	–100	–100	–100	Interp	–97.9	Interp	–97.9
508.8	–100	–100	–100	–100	Interp	Interp	-98	Interp
686	–100	–100	–100	–100	–100	–100	–100	–100
3 575	–100	–100	–100	–100	–100	–100	–100	–100
3 750	–80	–80	–80	–80	–80	–80	–80	–80
3 750	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2
5 100	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp
5 200	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7
5 200	–80	–80	–80	–80	–80	–80	–80	–80
5 375	–100	–100	–100	–100	–100	–100	–100	–100

Table B.6B – VTU-R limit PSD masks for band plan 998 (and its extensions) with highest used frequency of 30 MHz or 35.328 MHz

Name	B8-13	B8-14	B8-15	B8-16	B8-19	B8-20	B8-21	B8-22
Long name	998 E30-M2x-NUS0	998 E30-M2x-NUS0-M	998 ADE30-M2x-NUS0-M	998 ADE30-M2x-NUS0-A	998 E35-M2x-A	998 ADE35-M2x-A	998 ADE35-M2x-B	998 ADE35-M2x-M
kHz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz
8 325	–100	–100	–100	–100	–100	–100	–100	–100
8 500	–80	–80	–80	–80	–80	–80	–80	–80
8 500	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8
10 000	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5
12 000	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5
12 000	–56.5	–56.5	–80	–80	–56.5	–80	–80	–80
12 175	–56.5	–56.5	–100	–100	–56.5	–100	–100	–100
14 000	–56.5	–56.5	–100	–100	–56.5	–100	–100	–100
14 000	–80	–80	–100	–100	–80	–100	–100	–100
14 175	–100	–100	–100	–100	–100	–100	–100	–100
21 275	–100	–100	–100	–100	–100	–100	–100	–100
21 450	–80	–80	–100	–100	–100	–100	–100	–100
21 450	–56.5	–56.5	–100	–100	–100	–100	–100	–100
24 715	–56.5	–56.5	–100	–100	–100	–100	–100	–100
24 890	–56.5	–56.5	–80	–80	–100	–100	–100	–100
24 890	–80	–80	–56.5	–56.5	–100	–100	–100	–100
25 065	–100	–100	–56.5	–56.5	–100	–100	–100	–100
30 000	–100	–100	–56.5	–56.5	–100	–100	–100	–100
30 000	–110	–110	–80	–80	–110	–110	–110	–110
30 175	–110	–110	–110	–110	–110	–110	–110	–110
35 328	–110	–110	–110	–110	–110	–110	–110	–110
> 35 328	–110	–110	–110	–110	–110	–110	–110	–110

Table B.6B – VTU-R limit PSD masks for band plan 998 (and its extensions) with highest used frequency of 30 MHz or 35.328 MHz

Name	B8-13	B8-14	B8-15	B8-16	B8-19	B8-20	B8-21	B8-22
Long name	998 E30- M2x- NUS0	998 E30- M2x- NUS0-M	998 ADE30- M2x- NUS0-M	998 ADE30- M2x- NUS0-A	998 E35- M2x-A	998 ADE35- M2x-A	998 ADE35- M2x-B	998 ADE35- M2x-M
kHz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz
NOTE – The PSD values between breakpoints including the values marked by "Interp" shall be obtained by interpolation between adjacent breakpoints as follows: – below 3 575 kHz on a dB/log(*f*) basis; and – above 3 575 kHz on a dB/*f* basis.								

B.2.5 VTU-O Limit PSD masks for band plan 998 (and its extensions)

The VTU-O limit PSD masks for band plan 998 (and its extensions) with a highest used upstream or downstream frequency of 12 MHz or 17.664 MHz (see Table B.3 for the band plan 998 PSD mask options) are shown in Table B.7A.

Table B.7A– VTU-O limit PSD masks for band plan 998 (and its extensions) with a highest used frequency of 12 MHz or 17.664 MHz

Name	B8-4	B8-5	B8-6	B8-7	B8-8	B8-9	B8-10	B8-11	B8-12	B8-17	B8-18
Long name	998- M2x-A	998- M2x-M	998- M2x-B	998- M2x- NUS0	998 E17- M2x- NUS0	998 E17- M2x- NUS0-M	998 ADE17- M2x- NUS0-M	998 ADE17- M2x-A	998 ADE17- M2x-B	998 ADE17- M2x-M	998 E17- M2x-A
kHz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz
0	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5
4	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5
4	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5
80	–72.5	–92.5	–92.5	–72.5	–72.5	–92.5	–92.5	–72.5	–92.5	–92.5	–72.5

Table B.7A– VTU-O limit PSD masks for band plan 998 (and its extensions) with a highest used frequency of 12 MHz or 17.664 MHz

Name	B8-4	B8-5	B8-6	B8-7	B8-8	B8-9	B8-10	B8-11	B8-12	B8-17	B8-18
Long name	**998-M2x-A**	**998-M2x-M**	**998-M2x-B**	**998-M2x-NUS0**	**998 E17-M2x-NUS0**	**998 E17-M2x-NUS0-M**	**998 ADE17-M2x-NUS0-M**	**998 ADE17-M2x-A**	**998 ADE17-M2x-B**	**998 ADE17-M2x-M**	**998 E17-M2x-A**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
101.2	Interp	–92.5	–92.5	Interp	Interp	–92.5	–92.5	Interp	–92.5	–92.5	Interp
138	–44.2	Interp	Interp	–44.2	–44.2	Interp	Interp	–44.2	Interp	Interp	–44.2
138	–36.5	Interp	Interp	–36.5	–36.5	Interp	Interp	–36.5	Interp	Interp	–36.5
227.11	–36.5	–62	–62	–36.5	–36.5	–62	–62	–36.5	–62	–62	–36.5
276	–36.5	–48.5	–48.5	–36.5	–36.5	–48.5	–48.5	–36.5	–48.5	–48.5	–36.5
276	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5
1 104	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5
1 622	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5
2 208	–48	–48	–48	–48	–48	–48	–48	–48	–48	–48	–48
2 249	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp
2 500	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp
3 750	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2
3 750	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80
3 925	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
5 025	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
5 200	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80
5 200	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7
8 500	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8
8 500	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80	–80
8 675	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
11 825	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100

Table B.7A– VTU-O limit PSD masks for band plan 998 (and its extensions) with a highest used frequency of 12 MHz or 17.664 MHz

Name	B8-4	B8-5	B8-6	B8-7	B8-8	B8-9	B8-10	B8-11	B8-12	B8-17	B8-18
Long name	**998-M2x-A**	**998-M2x-M**	**998-M2x-B**	**998-M2x-NUS0**	**998 E17-M2x-NUS0**	**998 E17-M2x-NUS0-M**	**998 ADE17-M2x-NUS0-M**	**998 ADE17-M2x-A**	**998 ADE17-M2x-B**	**998 ADE17-M2x-M**	**998 E17-M2x-A**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
12 000	–100	–100	–100	–100	–100	–100	–80	–80	–80	–80	–100
12 000	–100	–100	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5	–100
13 825	–100	–100	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5	–100
14 000	–100	–100	–100	–100	–80	–80	–56.5	–56.5	–56.5	–56.5	–80
14 000	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
17 664	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
21 000	–100	–100	–100	–100	–80	–80	–80	–80	–80	–80	–80
21 450	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
30 000	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
30 000	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110
30 175	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110
> 30 175	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110	–110

NOTE – The PSD values between breakpoints including the values marked by "Interp" shall be obtained by interpolation between adjacent breakpoints as follows:

– below f_1 on a dB/log(f) basis; and
– above f_1 on a dB/f basis,

where f_1 is defined in Table B.1 as either 138 kHz or 276 kHz.

The VTU-O limit PSD masks for band plan 998 (and its extensions) with a highest used upstream or downstream frequency of 30 MHz or 35.328 MHz (see Table B.3 for the band plan 998 PSD mask options) are shown in Table B.7B.

Table B.7B – VTU-O limit PSD masks for band plan 998 (and its extensions) with a highest used frequency of 30 MHz or 35.328 MHz

Name	**B8-13**	**B8-14**	**B8-15**	**B8-16**	**B8-19**	**B8-20**	**B8-21**	**B8-22**
Long name	**998 E30-M2x-NUS0**	**998 E30-M2x-NUS0-M**	**998 ADE30-M2x-NUS0-M**	**998 ADE30-M2x-NUS0-A**	**998 E35-M2x-A**	**998 ADE35-M2x-A**	**998 ADE35-M2x-B**	**998 ADE35-M2x-M**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
0	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5
4	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5
4	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5
80	–72.5	–92.5	–92.5	–72.5	–72.5	–72.5	–92.5	–92.5
101.2	Interp	–92.5	–92.5	Interp	Interp	Interp	–92.5	–92.5
138	–44.2	Interp	Interp	–44.2	–44.2	–44.2	Interp	Interp
138	–36.5	Interp	Interp	–36.5	–36.5	–36.5	Interp	Interp
227.11	–36.5	–62	–62	–36.5	–36.5	–36.5	–62	–62
276	–36.5	–48.5	–48.5	–36.5	–36.5	-36.5	–48.5	–48.5
276	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5
1 104	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5
1 622	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5
2 208	–48	–48	–48	–48	–48	–48	–48	–48
3 750	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2
3 750	–80	–80	–80	–80	–80	–80	–80	–80
3 925	–100	–100	–100	–100	–100	–100	–100	–100
5 025	–100	–100	–100	–100	–100	–100	–100	–100
5 200	–80	–80	–80	–80	–80	–80	–80	–80
5 200	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7
8 500	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8
8 500	–80	–80	–80	–80	–80	–80	–80	–80
8 675	–100	–100	–100	–100	–100	–100	–100	–100

Table B.7B – VTU-O limit PSD masks for band plan 998 (and its extensions) with a highest used frequency of 30 MHz or 35.328 MHz

Name	B8-13	B8-14	B8-15	B8-16	B8-19	B8-20	B8-21	B8-22
Long name	998 E30- M2x- NUS0	998 E30- M2x- NUS0-M	998 ADE30- M2x- NUS0-M	998 ADE30- M2x- NUS0-A	998 E35- M2x-A	998 ADE35- M2x-A	998 ADE35- M2x-B	998 ADE35- M2x-M
kHz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz	dBm/ Hz
11 825	–100	–100	–100	–100	–100	–100	–100	–100
12 000	–100	–100	–80	–80	–100	–80	–80	–80
12 000	–100	–100	–56.5	–56.5	–100	–56.5	–56.5	–56.5
13 825	–100	–100	–56.5	–56.5	–100	–56.5	–56.5	–56.5
14 000	–80	–80	–56.5	–56.5	–80	–56.5	–56.5	–56.5
14 000	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
21 450	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
21 450	–80	–80	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
21 625	–100	–100	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
24 715	–100	–100	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
24 890	–80	–80	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
24 890	–56.5	–56.5	–80	–80	–56.5	–56.5	–56.5	–56.5
25 065	–56.5	–56.5	–100	–100	–56.5	–56.5	–56.5	–56.5
30 000	–56.5	–56.5	–100	–100	–56.5	–56.5	–56.5	–56.5
30 000	–80	–80	–110	–110	–73	–73	–73	–73
30 175	–110	–110	–110	–110	Interp	Interp	Interp	Interp
35 328	–110	–110	–110	–110	–73.4	–73.4	–73.4	–73.4
37 000	–110	–110	–110	–110	–83	–83	–83	-83
40 656	–110	–110	–110	–110	–110	–110	–110	–110
> 40 656	–110	–110	–110	–110	-110	–110	–110	–110
NOTE – The PSD values between breakpoints including the values marked by "Interp" shall be obtained by interpolation between adjacent breakpoints as follows:								

Table B.7B – VTU-O limit PSD masks for band plan 998 (and its extensions) with a highest used frequency of 30 MHz or 35.328 MHz

Name	B8-13	B8-14	B8-15	B8-16	B8-19	B8-20	B8-21	B8-22
Long name	998 E30-M2x-NUS0	998 E30-M2x-NUS0-M	998 ADE30-M2x-NUS0-M	998 ADE30-M2x-NUS0-A	998 E35-M2x-A	998 ADE35-M2x-A	998 ADE35-M2x-B	998 ADE35-M2x-M
kHz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz	dBm/Hz
– below f_1 on a dB/log(f) basis; and – above f_1 on a dB/f basis, where f_1 is defined in Table B.1 as either 138 kHz or 276 kHz.								

B.3 UPBO reference PSDs

UPBO parameters '*a*' and '*b*' are set by network management.

NOTE – The parameters '*a*' and '*b*' are expected to be uniform across all lines sharing a section of cable plant.

B.4 Template PSD

B.4.1 Definition

The Template PSD is set to 3.5 dB below the PSD mask in frequency bands in which the PSD is at or above −96.5 dBm/Hz. Elsewhere the template is set to −100 dBm/Hz below 4 MHz, −110 dBm/Hz between 4 MHz and f_3, or −112 dBm/Hz between f_3 and 35.328 MHz, where f_3 is defined in Table B.1. These values are chosen to satisfy the requirements of clause 7.2.2.

B.4.2 Narrow-band PSD verification

Narrow-band compliance with the PSD masks in this annex shall be verified by power measurements using a 10-kHz measurement bandwidth centred on the frequency in question above 4 kHz, and in a 100-Hz measurement bandwidth in the band up to 4 kHz.

B.4.3 Use in simulation (Informative)

The Template PSD may be used in simulations of VDSL2 performance as representative of an average transmitter conformant with the associated Limit PSD mask.

B.5 Compliance

Compliance requires conformance with at least one Limit PSD mask.

Annex C

Region C (Japan)

(This annex forms an integral part of this Recommendation.)

C.1 Band plan

The band plan shall be specified as shown in Figure C.1. According to the profiles defined in Table 6-1, adequate subsets of US0, DS1, US1, DS2, US2, DS3, and US3 shall be selected. The transition frequency between US0 and DS1 is 138 kHz or 276 kHz as defined in C.2.1.

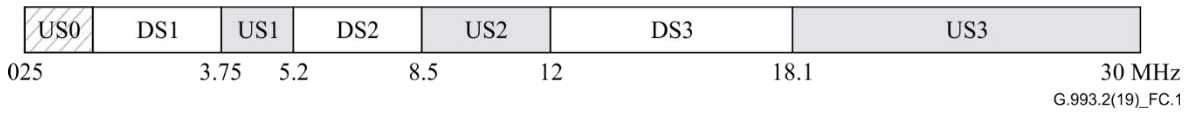

Figure C.1 – The band plan between 25 kHz and 30 MHz

C.2 Limit PSD masks

C.2.1 VDSL2 system operating at frequencies above the POTS band

The frequencies above 25 kHz are used for VDSL2. The downstream PSD shall comply with the Limit PSD masks defined in Table C.1, Table C.2, Table C.5 or Table C.6 and the upstream PSD shall comply with the Limit PSD masks defined in Table C.3, Table C.4, Table C.7 or Table C.8. Other PSD limitations are for further study.

Table C.1 – VTU-O limit PSD mask (VDSL2 above POTS band; 25-138 kHz Type(b))

Band attribute	Frequency band f (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
DS1	$0 < f < 0.12$	–120	–
	$0.12 \le f \le 0.138$	$-60 + (50/0.018) \times (f - 0.138)$	–
	$0.138 < f < 3.75$	–60 + 3.5 (= –56.5)	–
	$3.75 \le f \le 3.925$	$-80 - (20/0.175) \times (f - 3.75)$	–
	$3.925 < f < 5.025$	–100	–50
	$5.025 \le f \le 5.2$	$-80 + (20/0.175) \times (f - 5.2)$	–
DS2	$5.2 < f < 8.5$	–60 + 3.5 (= –56.5)	–
	$8.5 \le f \le 8.675$	$-80 - (20/0.175) \times (f - 8.5)$	–
	$8.675 < f < 11.825$	–100	–52
	$11.825 \le f \le 12$	$-80 + (20/0.175) \times (f - 12)$	–

Table C.1 – VTU-O limit PSD mask (VDSL2 above POTS band; 25-138 kHz Type(b))

Band attribute	Frequency band *f* (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
DS3	12 < *f* < 18.1	–60 + 3.5 (= –56.5)	–
	18.1 ≤ *f* ≤ 18.275	–80 – (20/0.175) × (*f* – 18.1)	–
	18.275 < *f* < 30	–100	–52
	30 ≤ *f*	–110	–
NOTE 1 – All PSD and power measurements are in 100 Ω. NOTE 2 – The limit PSD mask level shall be measured with a 10-kHz resolution bandwidth. NOTE 3 – The maximum power in a 1-MHz sliding window shall be measured with a 1-MHz resolution bandwidth. NOTE 4 – The requirements for the stopband PSD are compliant with clause 7.2.2.			

Table C.2 – VTU-O limit PSD mask (VDSL2 above POTS band; 25-276 kHz Type(b))

Band attribute	Frequency band *f* (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
DS1	0 < *f* < 0.12	–120	–
	0.12 ≤ *f* < 0.225	–110	–
	0.225 ≤ *f* ≤ 0.276	–60 + (50/0.051) × (*f* – 0.276)	–
	0.276 < *f* < 3.75	–60 + 3.5 (= –56.5)	–
	3.75 ≤ *f* ≤ 3.925	–80 – (20/0.175) × (*f* – 3.75)	–
	3.925 < *f* < 5.025	–100	–50
	5.025 ≤ *f* ≤ 5.2	–80 + (20/0.175) × (*f* – 5.2)	–
DS2	5.2 < *f* < 8.5	–60 + 3.5 (= –56.5)	–
	8.5 ≤ *f* ≤ 8.675	–80 – (20/0.175) × (*f* – 8.5)	–
	8.675 < *f* < 11.825	–100	–52
	11.825 ≤ *f* ≤ 12	–80 + (20/0.175) × (*f* – 12)	–
DS3	12 < *f* < 18.1	–60 + 3.5 (= –56.5)	–
	18.1 ≤ *f* ≤ 18.275	–80 – (20/0.175) × (*f* – 18.1)	–
	18.275 < *f* < 30	–100	–52
	30 ≤ *f*	–110	–
NOTE 1 – All PSD and power measurements are in 100 Ω. NOTE 2 – The limit PSD mask level shall be measured with a 10-kHz resolution bandwidth. NOTE 3 – The maximum power in a 1-MHz sliding window shall be measured with a 1-MHz resolution bandwidth. NOTE 4 – The requirements for the stopband PSD are compliant with clause 7.2.2.			

Table C.3 – VTU-R Limit PSD mask (VDSL2 above POTS band; 25-138 kHz Type(b))

Band attribute	Frequency band f (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
US0	$0 < f < 0.004$	–97.5	–
	$0.004 \leq f \leq 0.025875$	$-92.5 + 13.4 \times \log_2(f/0.004)$	–
	$0.025875 < f < 0.138$	–60 + 3.5 (= –56.5)	–
	$0.138 \leq f \leq 0.210$	$-56.5 - 72 \times \log_2(f/0.138)$	–
	$0.210 < f < 3.575$	100	–
	$3.575 \leq f \leq 3.75$	$-80 + (20/0.175) \times (f - 3.75)$	–
US1	$3.75 < f < 5.2$	–60 + 3.5 (= –56.5)	–
	$5.2 \leq f \leq 5.375$	$-80 - (20/0.175) \times (f - 5.2)$	–
	$5.375 < f < 8.325$	–100	–52
	$8.325 \leq f \leq 8.5$	$-80 + (20/0.175) \times (f - 8.5)$	–
US2	$8.5 < f < 12$	–60 + 3.5 (= –56.5)	–
	$12 \leq f \leq 12.175$	$-80 - (20/0.175) \times (f - 12)$	–
	$12.175 < f < 17.925$	–100	–52
	$17.925 \leq f \leq 18.1$	$-80 + (20/0.175) \times (f - 18.1)$	–
US3	$18.1 < f < 30$	–60 + 3.5 (= –56.5)	–
	$30 \leq f \leq 30.175$	$-80 - (30/0.175) \times (f - 30)$	–
	$30.175 < f$	–110	–

NOTE 1 – All PSD and power measurements are in 100 Ω.

NOTE 2 – The limit PSD mask level shall be measured with a 10-kHz resolution bandwidth.

NOTE 3 – The maximum power in a 1-MHz sliding window shall be measured with a 1-MHz resolution bandwidth.

NOTE 4 – The requirements for the stopband PSD are compliant with clause 7.2.2.

Table C.4 – VTU-R Limit PSD mask (VDSL2 above POTS band; 25-276 kHz Type(b))

Band attribute	Frequency band f (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
US0	$0 < f < 0.004$	–97.5	–
	$0.004 \leq f \leq 0.025875$	$-92.5 + 13.4 \times \log_2(f/0.004)$	_
	$0.025875 < f < 0.276$	–60 + 3.5 (= –56.5)	_
	$0.276 \leq f \leq 0.420$	$-56.5 - 72 \times \log_2(f/0.276)$	_
	$0.420 < f < 3.575$	–100	_
	$3.575 \leq f \leq 3.75$	$-80 + (20/0.175) \times (f - 3.75)$	_
US1	$3.75 < f < 5.2$	–60 + 3.5 (= –56.5)	_
	$5.2 \leq f \leq 5.375$	$-80 - (20/0.175) \times (f - 5.2)$	_
	$5.375 < f < 8.325$	–100	–52
	$8.325 \leq f \leq 8.5$	$-80 + (20/0.175) \times (f - 8.5)$	_
US2	$8.5 < f < 12$	–60 + 3.5 (= –56.5)	_
	$12 \leq f \leq 12.175$	$-80 - (20/0.175) \times (f - 12)$	_
	$12.175 < f < 17.925$	–100	–52
	$17.925 \leq f \leq 18.1$	$-80 + (20/0.175) \times (f - 18.1)$	_
US3	$18.1 < f < 30$	–60 + 3.5 (= –56.5)	_
	$30 \leq f \leq 30.175$	$-80 - (30/0.175) \times (f - 30)$	_
	$30.175 < f$	–110	_

NOTE 1 – All PSD and power measurements are in 100 Ω.

NOTE 2 – The Limit PSD mask level shall be measured with a 10-kHz resolution bandwidth.

NOTE 3 – The maximum power in a 1-MHz sliding window shall be measured with a 1-MHz resolution bandwidth.

NOTE 4 – The requirements for the stopband PSD are compliant with clause 7.2.2.

Table C.5 – VTU-O Limit PSD mask (VDSL2 above POTS band; 25-138 kHz Type(co))

Band attribute	Frequency band f (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
DS1	$0 < f < 0.004$	–97.5	–
	$0.004 \le f < 0.08$	$-92.5 + 4.63 \times \log_2(f/0.004)$	_
	$0.08 \le f \le 0.138$	$-72.5 + 36 \times \log_2(f/0.08)$	_
	$0.138 < f \le 1.104$	–40 + 3.5 (= –36.5)	_
	$1.104 < f < 1.622$	$-36.5 - 18 \times \log_2(f/1.104)$	_
	$1.622 \le f < 3.75$	$-46.5 - 2.9 \times \log_2(f/1.622)$	_
	$3.75 \le f \le 3.925$	$-80 - (20/0.175) \times (f - 3.75)$	
	$3.925 < f < 5.025$	–100	–50
	$5.025 \le f \le 5.2$	$-80 + (20/0.175) \times (f - 5.2)$	_
DS2	$5.2 < f < 8.5$	–55 + 3.5 (= –51.5)	_
	$8.5 \le f \le 8.675$	$-80 - (20/0.175) \times (f - 8.5)$	_
	$8.675 < f < 30$	–100	–52
	$30 \le f$	–110	–

NOTE 1 – All PSD and power measurements are in 100 Ω.

NOTE 2 – The Limit PSD mask level shall be measured with a 10-kHz resolution bandwidth.

NOTE 3 – The maximum power in a 1-MHz sliding window shall be measured with a 1-MHz resolution bandwidth.

NOTE 4 – The requirements for the stopband PSD are compliant with clause 7.2.2.

Table C.6 – VTU-O Limit PSD mask (VDSL2 above POTS band; 25-276 kHz Type(co))

Band attribute	Frequency band f (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
DS1	$0 < f < 0.004$	–97.5	–
	$0.004 \le f < 0.1012$	–90	_
	$0.1012 \le f < 0.2271$	$-90 + 24 \times \log_2(f/0.1012)$	_
	$0.2271 \le f \le 0.276$	$-62 + 63 \times \log_2(f/0.2271)$	_
	$0.276 < f \le 1.104$	–40 + 3.5 (= –36.5)	_
	$1.104 < f < 1.622$	$-36.5 - 18 \times \log_2(f/1.104)$	_
	$1.622 \le f < 3.75$	$-46.5 - 2.9 \times \log_2(f/1.622)$	_
	$3.75 \le f \le 3.925$	$-80 - (20/0.175) \times (f - 3.75)$	
	$3.925 < f < 5.025$	–100	–50
	$5.025 \le f \le 5.2$	$-80 + (20/0.175) \times (f - 5.2)$	_

Table C.6 – VTU-O Limit PSD mask (VDSL2 above POTS band; 25-276 kHz Type(co))

Band attribute	Frequency band f (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
DS2	$5.2 < f < 8.5$	–55 + 3.5 (= –51.5)	–
	$8.5 \leq f \leq 8.675$	$-80 - (20/0.175) \times (f - 8.5)$	–
	$8.675 < f < 30$	–100	–52
	$30 \leq f$	–110	–
NOTE 1 – All PSD and power measurements are in 100 Ω. NOTE 2 – The Limit PSD mask level shall be measured with a 10-kHz resolution bandwidth. NOTE 3 – The maximum power in a 1-MHz sliding window shall be measured with a 1-MHz resolution bandwidth. NOTE 4 – The requirements for the stopband PSD are compliant with clause 7.2.2.			

Table C.7 – VTU-R Limit PSD mask (VDSL2 above POTS bands; 25-138 kHz Type(co))

Band attribute	Frequency band f (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
US0	$0 < f < 0.004$	–97.5	–
	$0.004 \leq f \leq 0.025875$	$-92.5 + 21.5 \times \log_2(f/0.004)$	–
	$0.025875 < f < 0.138$	–38 + 3.5 (= –34.5)	–
	$0.138 \leq f < 0.24292$	$-34.5 - 72 \times \log_2(f/0.138)$	–
	$0.24292 \leq f \leq 0.686$	$-93.2 - 15 \times \log_{10}(f/0.24292)$	–
	$0.686 < f < 3.575$	–100	–
	$3.575 \leq f \leq 3.75$	$-80 + (20/0.175) \times (f - 3.75)$	–
US1	$3.75 < f < 5.2$	–53 + 3.5 (= –49.5)	–
	$5.2 \leq f \leq 5.375$	$-80 - (20/0.175) \times (f - 5.2)$	–
	$5.375 < f < 8.325$	–100	–52
	$8.325 \leq f \leq 8.5$	$-80 + (20/0.175) \times (f - 8.5)$	–

Table C.7 – VTU-R Limit PSD mask (VDSL2 above POTS bands; 25-138 kHz Type(co))

Band attribute	Frequency band f (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
US2	$8.5 < f < 12$	–54 + 3.5 (= –50.5)	–
	$12 \leq f \leq 12.175$	$–80 – (20/0.175) \times (f – 12)$	–
	$12.175 < f < 30$	–100	–52
	$30 \leq f$	–110	–
NOTE 1 – All PSD and power measurements are in 100 Ω. NOTE 2 – The Limit PSD mask level shall be measured with a 10-kHz resolution bandwidth. NOTE 3 – The maximum power in a 1-MHz sliding window shall be measured with a 1-MHz resolution bandwidth. NOTE 4 – The requirements for the stopband PSD are compliant with clause 7.2.2.			

Table C.8 – VTU-R Limit PSD mask (VDSL2 above POTS band; 25-276 kHz Type(co))

Band attribute	Frequency band f (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
US0	$0 < f < 0.004$	–97.5	–
	$0.004 \leq f \leq 0.025875$	$–92.5 + 20.4 \times \log_2(f/0.004)$	–
	$0.025875 < f < 0.276$	–41 + 3.5 (= –37.5)	–
	$0.276 \leq f < 0.49341$	$–37.5 – 72 \times \log_2(f/0.276)$	–
	$0.49341 \leq f \leq 0.686$	$–97.9 – 15 \times \log_{10}(f/0.49341)$	–
	$0.686 < f < 3.575$	–100	–
	$3.575 \leq f \leq 3.75$	$–80 + (20/0.175) \times (f – 3.75)$	–
US1	$3.75 < f < 5.2$	–53 + 3.5 (= –49.5)	–
	$5.2 \leq f \leq 5.375$	$–80 – (20/0.175) \times (f – 5.2)$	–
	$5.375 < f < 8.325$	–100	–52
	$8.325 \leq f \leq 8.5$	$–80 + (20/0.175) \times (f – 8.5)$	–

Table C.8 – VTU-R Limit PSD mask (VDSL2 above POTS band; 25-276 kHz Type(co))

Band attribute	Frequency band *f* (MHz)	Limit PSD mask level (dBm/Hz)	Maximum power limitation in a 1-MHz sliding window (dBm)
US2	8.5 < *f* < 12	–54 + 3.5 (= –50.5)	–
	12 ≤ *f* ≤ 12.175	–80 – (20/0.175) × (*f* – 12)	–
	12.175 < *f* < 30	–100	–52
	30 ≤ *f*	–110	–
NOTE 1 – All PSD and power measurements are in 100 Ω. NOTE 2 – The Limit PSD mask level shall be measured with a 10-kHz resolution bandwidth. NOTE 3 – The maximum power in a 1-MHz sliding window shall be measured with a 1-MHz resolution bandwidth. NOTE 4 – The requirements for the stopband PSD are compliant with clause 7.2.2.			

C.2.2 VDSL2 system operating at frequencies above the TCM-ISDN DSL band

The frequencies above 640 kHz are used for VDSL2. The frequencies below 320 kHz are used for time compression multiplexed – integrated services digital network (TCM-ISDN) DSL. The band between 320 kHz and 640 kHz is a guard band. US0 shall not be used and DS1 shall start at 640 kHz.

The Limit PSD masks are defined in Tables C.9 and C.10 below. Other PSDs are for further study.

Table C.9 – VTU-O Limit PSD mask (VDSL2 above TCM-ISDN band)

Band attribute	Frequency band *f* (MHz)	Limit PSD mask level (dBm/Hz) (Notes 1, 2 and 4)	Maximum power limitation in a 1-MHz sliding window (dBm) (Notes 1, 3 and 4)
DS1	0 < *f* < 0.12	−120	
	0.12 ≤ *f* < 0.225	−110	
	0.225 ≤ *f* < 0.465	−100	
	0.465 ≤ *f* ≤ 0.640	−60 + (40/0.175) × (*f* − 0.64)	
	0.640 < *f* < 3.75	−60 + 3.5 (= −56.5)	
	3.75 ≤ *f* ≤ 3.925	−80 − (20/0.175) × (*f* − 3.75)	
	3.925 < *f* < 5.025	−100	−50
	5.025 ≤ *f* ≤ 5.2	−80 + (20/0.175) × (*f* − 5.2)	
DS2	5.2 < *f* < 8.5	−60 + 3.5 (= −56.5)	
	8.5 ≤ *f* ≤ 8.675	−80 − (20/0.175) × (*f* − 8.5)	
	8.675 < *f* < 11.825	−100	−52
	11.825 ≤ *f* ≤ 12	−80 + (20/0.175) × (*f* − 12)	

Table C.9 – VTU-O Limit PSD mask (VDSL2 above TCM-ISDN band)

Band attribute	Frequency band *f* (MHz)	Limit PSD mask level (dBm/Hz) (Notes 1, 2 and 4)	Maximum power limitation in a 1-MHz sliding window (dBm) (Notes 1, 3 and 4)
DS3	$12 < f < 18.1$	$-60 + 3.5$ (= -56.5)	
	$18.1 \le f \le 18.275$	$-80 - (20/0.175) \times (f - 18.1)$	
	$18.275 < f < 30$	-100	-52
	$30 \le f$	-110	

NOTE 1 – All PSD and power measurements are into 100 Ω.
NOTE 2 – The Limit PSD mask level shall be measured with a 10-kHz resolution bandwidth.
NOTE 3 – The maximum power in a 1-MHz sliding window shall be measured with a 1-MHz resolution bandwidth.
NOTE 4 – The requirements for the stopband PSD are compliant with clause 7.2.2.
NOTE 5 – The integral of the PSD does not exceed 11.0 dBm in the 30 MHz frequency range.
NOTE 6 – When SUPPORTEDCARRIERSds starts at 1 104 MHz, the Limit PSD mask below 1 104 MHz shall comply with Table F.4 of [ITU-T G.993.1].

Table C.10 – VTU-R Limit PSD mask (VDSL2 above TCM-ISDN band)

Band attribute	Frequency band *f* (MHz)	Limit PSD mask level (dBm/Hz) (Notes 1, 2 and 4)	Maximum power limitation in a 1-MHz sliding window (dBm) (Notes 1, 3 and 4)
US1	$0 < f < 0.12$	-120	
	$0.12 \le f < 0.225$	-110	
	$0.225 \le f < 3.575$	-100	
	$3.575 \le f \le 3.75$	$-80 + (20/0.175) \times (f - 3.75)$	
	$3.75 < f < 5.2$	$-60 + 3.5$ (= -56.5)	
	$5.2 \le f \le 5.375$	$-80 - (20/0.175) \times (f - 5.2)$	
	$5.375 < f < 8.325$	-100	-52
	$8.325 \le f \le 8.5$	$-80 + (20/0.175) \times (f - 8.5)$	
US2	$8.5 < f < 12$	$-60 + 3.5$ (= -56.5)	
	$12 \le f \le 12.175$	$-80 - (20/0.175) \times (f - 12)$	
	$12.175 < f < 17.925$	-100	-52
	$17.925 \le f \le 18.1$	$-80 + (20/0.175) \times (f - 18.1)$	

Table C.10 – VTU-R Limit PSD mask (VDSL2 above TCM-ISDN band)

Band attribute	Frequency band f (MHz)	Limit PSD mask level (dBm/Hz) (Notes 1, 2 and 4)	Maximum power limitation in a 1-MHz sliding window (dBm) (Notes 1, 3 and 4)
US3	$18.1 < f < 30$	$-60 + 3.5$ (= -56.5)	
	$30 \le f \le 30.175$	$-80 - (30/0.175) \times (f - 30)$	
	$30.175 < f$	-110	

NOTE 1 – All PSD and power measurements are into 100 Ω.

NOTE 2 – The Limit PSD mask level shall be measured with a 10-kHz resolution bandwidth.

NOTE 3 – The maximum power in a 1-MHz sliding window shall be measured with a 1-MHz resolution bandwidth.

NOTE 4 – The requirements for the stopband PSD are compliant with clause 7.2.2.

NOTE 5 – The integral of the PSD does not exceed 12.3 dBm in the 30 MHz frequency range.

C.3 VDSL2 system with PSD reduction at frequencies below DPBOFMAX

The downstream transmit PSD masks for frequencies below DPBOFMAX shall not exceed RESULTMASKds(f) defined in clause 7.3.1.2.13 of [ITU-T G.997.1]. An example set of parameters intended to protect ADSL2plus is described in Appendix I. The upstream transmit PSD mask for frequencies below DPBOFMAX shall comply with Table C.3, Table C.4, Table C.7, Table C.8 or Table C.10 For frequencies between DPBOFMAX and 30 MHz, the downstream transmit PSD mask shall comply with Table C.5 or Table C.9 and the upstream transmit PSD mask shall comply with Table C.7 or Table C.10. Other PSD limitations, including US0 power reduction, are for further study.

C.4 Upstream power back-off (UPBO) PSD masks

The VTU-R shall calculate the required UPBO and its upstream PSD mask as specified in clause 7.2.1.3.2.

The UPBO reference PSD, UPBOPSD*(f)*, is parameterized as $-a - b\sqrt{f}$ dBm/Hz, with f expressed in MHz.

For US1 and US2 as defined in Figure C.1, values of a and b are given in Table C.11. These values shall apply when the Limit PSD mask for US1 and US2 does not exceed –56.5 dBm/Hz.

When the Limit PSD mask for US1 and US2 is different from the one defined not to exceed −56.5 dBm/Hz, the values of a and b for UPBOPSD are for further study. For US3 defined not to exceed −56.5 dBm/Hz, the values of a and b for UPBOPSD are given in Table C.11.

Table C.11 – UPBOPSD parameters

		a	***b***
Limit PSD mask ≤ −56.5 dBm/Hz	US1	60	10.2
	US2	60	6.42
	US3	40 (Note)	0 (Note)
Other Limit PSD masks	US1	For further study	For further study
	US2		
	US3		
NOTE – ITU-T G.997.1 defines the set of parameter values *a* = 40 dBm/Hz, *b* = 0 dBm/Hz as a special configuration to disable UPBO in the respective upstream band.			

C.5 Service Splitter

See F.2 of [ITU-T G.993.1].

For operation according to Annex C, the requirements applying over a frequency band up to 12 MHz in [ITU-T G.993.1] shall be met over a frequency band up to 30 MHz.

However, the return loss of the POTS splitter in the band between 12 MHz and 30 MHz shall be measured as shown in Figure C.2.

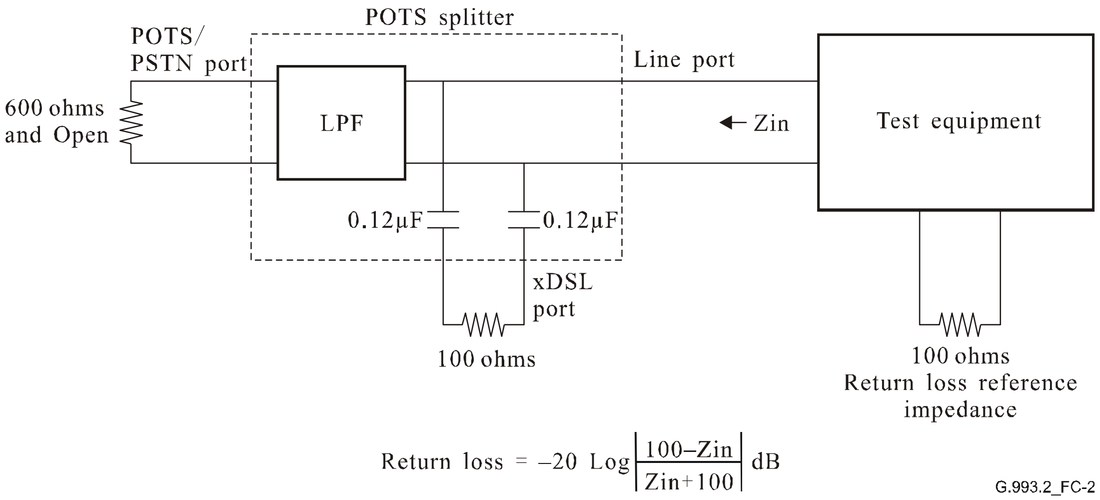

Figure C.2 – Impedance measurements in the band between 12 MHz and 30 MHz for the CO and remote POTS splitters

C.6 Test loops and crosstalk disturbers

C.6.1 Test loops

C.6.1.1 Loop configurations

For frequency bands below 12 MHz, see clause F.3.1.1of [ITU-T G.993.1]. For VDSL2 using frequency bands above 12 MHz, the following settings for bridged tap parameter Y_2 shall be added to test loop VLOOP-J3 (see Figure F.10 of [ITU-T G.993.1]):

Y_2 = 1-10 m at every 1 m step.

C.6.1.2 Primary line constants

See F.3.1.2 of [ITU-T G.993.1].

The equations of primary line constants are applicable up to 30 MHz.

C.6.1.3 Line transfer function and test loop characteristics

See F.3.1.3 of [ITU-T G.993.1].

C.6.2 Crosstalk disturbers

C.6.2.1 Disturber types

See F.3.2.1 of [ITU-T G.993.1].

The five disturber types shown below using ITU-T G.992.1 (Annex I), VDSL2 self, and PNT3 (in [ITU-T G.9954]) shall be added:

- Noise B_5 = 9 VDSL2 self NEXT and FEXT (see Tables C.1 to C.10 for the disturber PSD);
- Noise B_6 = 9 ADSL NEXT and FEXT (see Figure I.13 of [ITU-T G.992.1] (I.4.8.1 of [ITU-T G.992.1]) for the disturber PSD);
- Noise B_7 = 9 PNT3 (mask #1) NEXT (see Table 6-10 of [ITU-T G.9954] (mask #1) in clause 6.8.3.1 of [ITU-T G.9954] for the disturber PSD);
- Noise B_8 = 9 PNT3 (mask #2) NEXT (see Table 6-12 of [ITU-T G.9954]) (mask #2) in clause 6.8.3.1 of [ITU-T G.9954] for the disturber PSD); and
- Noise B_9 = 9 PNT3 (mask #3) NEXT (see Table 6-14 of [ITU-T G.9954]) (mask #3) in clause 6.8.3.1 of [ITU-T G.9954] for the disturber PSD).

Other disturbers are for further study.

C.6.2.2 Power spectral density of disturbers

See F.3.2.2 of [ITU-T G.993.1].

For Annex I of [ITU-T G.992.1], see Figure I.13 of [ITU-T G.992.1] (I.4.8.1 of [ITU-T G.992.1]). The disturber has an offset of −3.5 dB with respect to the peak mask defined in Figure I.13 of [ITU-T G.992.1]. For VDSL2 self, see Tables C.1 to C.10. In the in-band regions, the disturber has an offset of −3.5 dB with respect to the peak mask defined in Tables C.1 to C.10. For PNT3 (ITU-T G.9954), see Table 6-10 of [ITU-T G.9954] (mask #1), Table 6-12 of [ITU-T G.9954] (mask #2) and Table 6-14 of [ITU-T G.9954] (mask #3) in clause 6.8.3.1 of [ITU-T G.9954].

C.6.2.3 Power spectral density of crosstalk

See clause F.3.2.3 of [ITU-T G.993.1].

Annex D

Long Reach VDSL2

(This annex forms an integral part of this Recommendation.)

D.1 Introduction

This annex defines the Long Reach mode for VDSL2 without vectoring.

The Annex B of [ITU-T G.993.5] defines vectored long reach VDSL2. This annex is a delta specification to Annex B of [ITU-T G.993.5].

A VTU-R supporting operation according to this annex, shall also support operation according to Annex B of [ITU-T G.993.5].

A VTU-O supporting operation according to this annex, may also support operation according to Annex B of [ITU-T G.993.5].

If during the ITU-T G.994.1 handshake phase, VDSL2-LR operation is selected and operation according to [ITU-T G.993.5] is not selected, then the VTU-O and VTU-R shall operate according to this annex.

D.2 Overview of the initialization procedure

The VDSL2-LR initialization procedure includes two parts:

1) Regular ITU-T G.993.2 procedure (including ITU-T G.993.2 channel estimation) with minor modifications; and
2) Additional stages:
   - PROBING: During this stage, the VTU-R determines the length of the line and indicates to the VTU-O whether to continue the VDSL2-LR initialization in short-medium operation or in long loop operation. Following the indication from the VTU-R, both the VTU-O and the VTU-R continue the initialization of the line in short-medium loop operation or in long loop operation;
   - TRAINING: This stage is present if the VTU-R selected to continue the initialization of the line in long loop operation. During this stage, the VTU-O and VTU-R train the line for long loop operation.

The framework of the initialization procedure is presented in Figure D.1. It illustrates VDSL2-LR initialization (compared to regular ITU-T G.993.2 initialization), using the following notations for the exchanged signals:

- ITU-T G.993.2 signals – used if the line is a regular ITU-T G.993.2 line, i.e., not operating according to this annex (a regular ITU-T G.993.2 line);
- LR signals, short-medium – used if the line is selected during the PROBING stage to continue the VDSL2-LR initialization in short-medium loop operation (to become a short or medium VDSL2-LR line);
- LR signals, long – used if the line is selected during the PROBING stage to continue the VDSL2-LR initialization in long loop operation (for a long VDSL2-LR line).

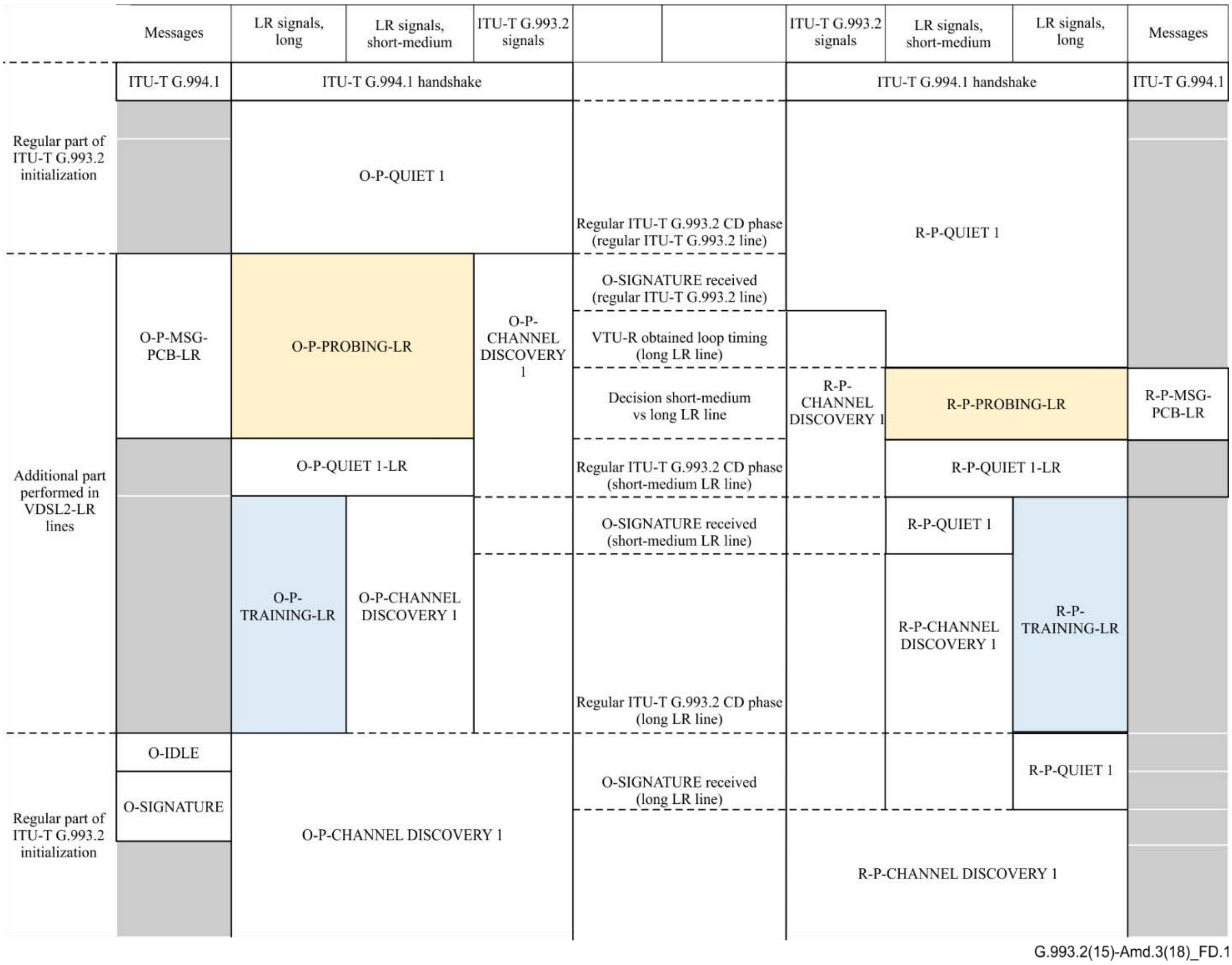

Figure D.1 – Overview of the VDSL2-LR initialization (compared to regular ITU-T G.993.2 initialization)

D.3 ITU-T G.994.1 handshake phase

See clause B.3 of [ITU-T G.993.5].

D.4 Signals sent by the VTU-O during the channel discovery phase

See clause B.4 of [ITU-T G.993.5] with the following differences:

- The length of O-P-VECTOR 0 shall be set to zero symbols;
- The length of O-P-VECTOR 1-LR shall be set to zero symbols;
- The O-P-VECTOR 1 shall be set to zero symbols;
- The O-P-QUIET 1 signal shall be followed by the O-P-PROBING-LR signals;
- If the initialization of the line shall be continued in short-medium operation, then the O-P-QUIET 1-LR signal shall be followed by the O-P-CHANNEL DISCOVERY 1 signal (sending O-IDLE) and the remainder of the channel discovery phase shall be as defined in clause 12.3.3;
- If the initialization of the line shall be continued in long loop operation, then the O-P-QUIET 1-LR signal shall be followed by the O-P-TRAINING-LR signal;
- The IDFT size during O-P-TRAINING-LR may be a size that is different from the Initial IDFT size indicated in the ITU-T G.994.1 CL message. The IDFT size (2N) shall be at least 2048 (i.e., $n \geq 11$), so that there is no image above the subcarrier with index 511;

- After O/R-P-TRAINING-LR signal exchange is complete, the line continues the regular ITU-T G.993.2 initialization. The O-P-TRAINING-LR signals shall be followed by the O-P-CHANNEL DISCOVERY 1 signal defined in clause 12.3.3.3.1.2 and the remainder of the channel discovery phase defined in clause 12.3.3;
- Clauses B.4.7 and B.4.8 of [ITU-T G.993.5] apply to the ITU-T G.993.2 channel discovery phase.

NOTE – VDSL2-LR long lines, VDSL2-LR short-medium lines and ITU-T G.993.2 lines may not have the O-SIGNATURE message sent at the same time.

D.5 Signals sent by the VTU-R during the channel discovery phase

See clause B.5 of [ITU-T G.993.5] with the following differences:

- The length of R-P-QUIET 2-LR shall be set to zero symbols;
- After O/R-P-TRAINING-LR signal exchange is complete, the line continues regular ITU-T G.993.2 initialization;
- The R-P-TRAINING-LR signals shall be followed by the R-P-QUIET 1 signal defined in clause 12.3.3.3.2.1 and the remainder of the channel discovery phase defined in clause 12.3.3;
- Clause B.5.6 of [ITU-T G.993.5] applies to the ITU-T G.993.2 channel discovery phase and clause B.5.7 of [ITU-T G.993.5] applies to the ITU-T G.993.2 training phase.

D.6 O/R-P-PROBING-LR signal exchange

See clause B.6 of [ITU-T G.993.5].

D.7 O/R-P-TRAINING-LR signal exchange

See clause B.7 of [ITU-T G.993.5] with the following differences:

- The first symbol of O-P-SEGUE 1-LR is used as reference time point to facilitate alignment between timing of VDSL-LR training and the ITU-T G.993.2 channel discovery (see clause 12.3.3);
- The O-P-PILOT-LR signal shall be as defined in clause D.7.1;
- The R-P-SEGUE 1-LR state shall be followed by the ITU-T G.993.2 R-P-QUIET 1 state.

D.7.1 O-P-PILOT-LR (replaces clause B.7.1.14 of ITU-T G.993.5)

In the O-P-PILOT-LR state, the VTU-O shall transmit an integer number of O-P-PILOT symbols. The duration of the O-P-PILOT-LR state shall be 128 symbols.

The O-P-PILOT is a non-periodic signal. The alignment of the O-P-PILOT symbols and the O-P-SEGUE 1-LR state shall use two reference points associated with the IDFT sample #0 of specific symbols. The IDFT sample #0 is defined as the first sample of the block of 2N time samples generated by the IDFT.

The first reference point shall be the IDFT sample #0 of the first symbol of the O-P-SEGUE 1-LR state, and the second reference point is the IDFT sample #0 of the first symbol of the O-P-PILOT-LR state, as shown in the Figure D.2.

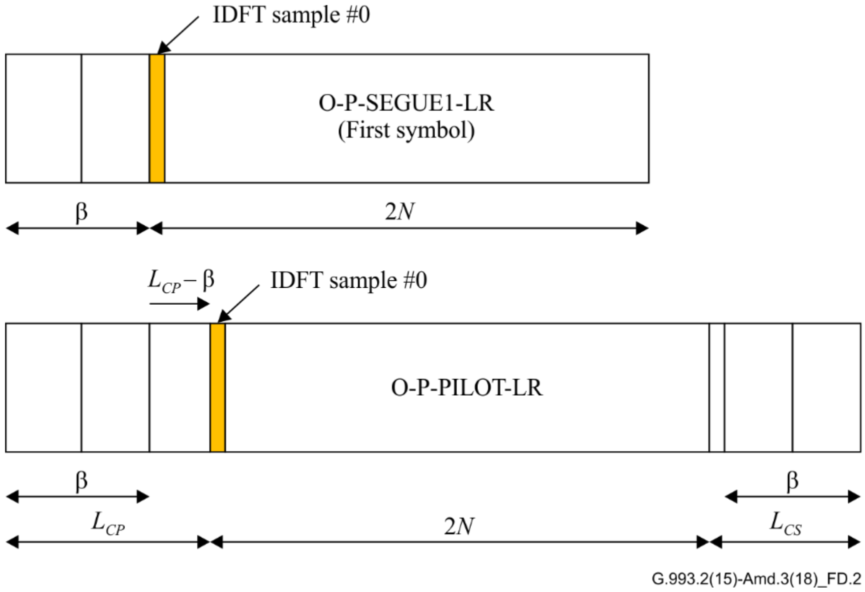

Figure D.2 – Reference samples for alignment of downstream symbols between the O-SEGUE 1-LR state and O-P-PILOT-LR state

The time offset expressed in samples between those reference points modulo the period of a DMT symbol with CE, i.e., $2N+L_{CE}$ samples, shall be as indicated by the VTU-O in the ITU-T G.994.1 Spar(2) codepoint "offset IDFT sample #0" indicated by the VTU-O. The parameter "offset IDFT sample #0" shall be an integer number of samples at the rate of 4.416 MHz.

NOTE – The value of this offset is equal to L_{CP}-β which is always less than or equal to L_{CE}, see Figure D.2. Knowledge of that offset by the receiver, allows VTU-R to derive the symbol timing during the O-P-PILOT-LR and transition into [ITU-T G.993.2] channel discovery phase with timing acquired in the VDSL2-LR TRAINING stage. This, in turn, allows to re-use TEQ settings and other transceiver settings obtained during the VDSL2-LR TRAINING stage.

The O-P-PILOT-LR state shall be followed by the O-P-CHANNEL DISCOVERY 1 signal and the remainder of the ITU-T G.993.2 channel discovery phase with amendments as specified in clause D.8.

D.8 ITU-T G.993.2 channel discovery phase and training phase in long loop operation

This clause contains additional requirements on the ITU-T G.993.2 channel discovery phase and training phase that apply if the long loop operation of VDSL2-LR is selected (see clauses B.4.8, B.4.9, B.5.6 and B.5.7 of [ITU-T G.993.5]).

The setting of the transmit path between the IDFT output and the corresponding U-interface of both the VTU-R and VTU-O that was established during the TRAINING stage shall be kept unchanged during the ITU-T G.993.2 channel discovery phase and training phase. The IDFT size and type of image used during the ITU-T G.993.2 channel discovery and training phases shall be the same as those used during the TRAINING stage.

D.8.1 ITU-T G.993.2 channel discovery phase in long loop operation

The SUPPORTEDCARRIERSds set shall be limited to subcarrier index 511.

The SUPPORTEDCARRIERSus set shall be limited to subcarrier index 31 for US0 type A, and to subcarrier index 63 for US0 types B and M.

D.8.1.1 Transition to ITU-T G.993.2 channel discovery phase

In the downstream direction, symbols in ITU-T G.993.2 channel discovery phase shall be aligned with symbols in O-P-PILOT-LR.

In the upstream, the transition from VDSL2-LR TRAINING stage to ITU-T G.993.2 CHANNEL DISCOVERY PHASE shall be aligned using two reference points associated with the IDFT sample #0 of specific symbols. The IDFT sample #0 is defined as the first sample of the block of 2N time samples generated by the IDFT.

The first reference point shall be the IDFT sample #0 of the first symbol of the R-P-SEGUE 1-LR state and the second reference point shall be the IDFT sample #0 of the first symbol of the R-P-CHANNEL DISCOVERY 1 signal, as shown in the Figure D.3.

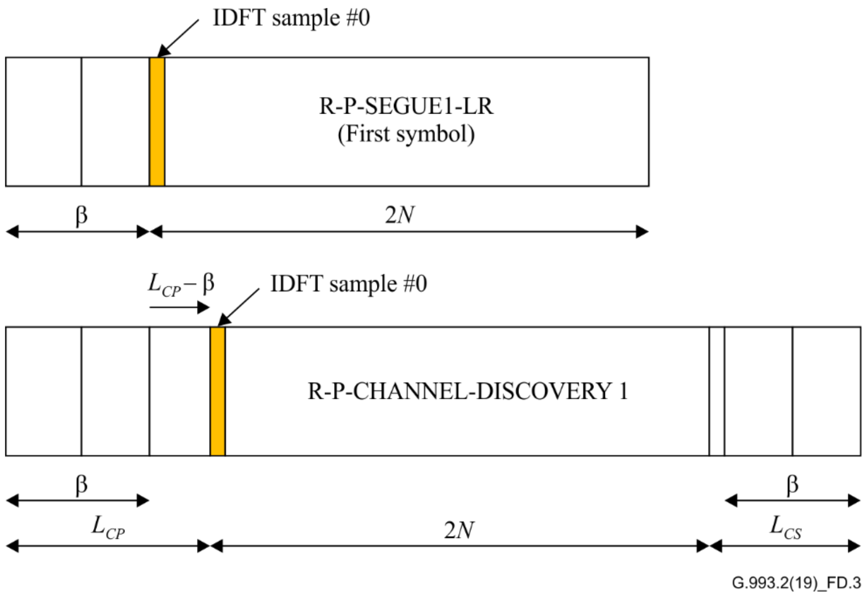

Figure D.3 – Reference samples for alignment of upstream symbols between the VDSL2-LR TRAINING stage and ITU-T G.993.2 channel discovery phase

The time offset expressed in samples between those reference points modulo the period of a DMT symbol with CE, i.e., $2N+L_{CE}$ samples, shall be as indicated by the VTU-R in the ITU-T G.994.1 Spar(2) codepoint "offset IDFT sample #0". The parameter "offset IDFT sample #0" indicated by the VTU-R shall be an integer number of samples at the rate of 276 kHz.

NOTE – The value of this offset is equal to L_{CP}-β, which is always less than or equal to L_{CE}, see Figure D.3. Knowledge of that offset by the VTU-O, allows to derive the symbol timing during the ITU-T G.993.2 channel discovery phase from the one acquired in the VDSL2-LR TRAINING stage. This, in turn, allows to re-use TEQ settings and other transceiver settings obtained during the VDSL2-LR TRAINING stage.

D.8.1.2 Use of PILOT during R-P-LINEPROBE

If the ITU-T G.993.2 R-P-LINEPROBE signal is requested, the VTU-O shall transmit O-P-PILOT 1 and transition to O-P-PERIODIC 1 640 symbols after the end of transmission of O-P-SYNCHRO 1. The O-P-PILOT 1 shall use the tone index indicated during the PROBING stage.

D.8.1.3 O-SIGNATURE (amends clause 12.3.3.2.1.1 of ITU-T G.993.2)

Field #8 "Downstream nominal maximum aggregate transmit power (MAXNOMATPds)" indicates the value of the control parameter *MAXNOMATPds*, which determines the maximum wide-band power that the VTU-O is allowed to transmit. The value of the MAXNOMATPds shall not exceed the minimum of the maximum aggregate downstream transmit power as defined in clause D.9 for the corresponding annex of [ITU-T G.993.2] and the MAXNOMATPds value configured in the CO-MIB, regardless of the particular G.993.2 profile selected during the ITU-T G.994.1 handshake phase of initialization.

D.8.1.4 PSD adjustments during ITU-T G.993.2 channel discovery phase

The PSD adjustments defined in ITU-T G.993.2 channel discovery phase include potential changes of the downstream highest used subcarrier and the actual downstream transmit PSD, which may result in a different downstream transmit PSD than the one defined during the PROBING stage. To avoid changes in the transmission channel and corresponding degradations in tuning of the TEQ, the mentioned adjustment of the PSD shall be done exclusively in frequency domain.

D.8.2 ITU-T G.993.2 training phase in long loop operation

During the transition to the ITU-T G.993.2 training phase, the VTU-R shall keep symbol timing. To keep the position of the IDFT sample #0 between the channel discovery and the training phases in upstream, the duration of R-P-QUIET 2 shall be an integer number of DMT symbols.

D.9 Definition of Limit PSD masks

See clause B.9 of [ITU-T G.993.5].

D.10 Management

See clause B.10 of [ITU-T G.993.5].

D.11 Nominal aggregate transmit power (NOMATP)

See clause B.11 of [ITU-T G.993.5].

Annex E

For further study.

Annex F

For further study.

Annex G

For further study.

Annex H

For further study.

Annex J

For further study.

Annex K

For further study.

Annex L

TPS-TC functional descriptions

(This annex forms an integral part of this Recommendation.)

This annex contains the functional descriptions of various TPS-TC types that may be used within the ITU-T G.993.2 transceivers.

L.1 STM transmission convergence (STM-TC) function

L.1.1 Scope

The STM-TC function provides procedures for the transport of one STM-TC stream in either the upstream or downstream direction. Octet boundaries and the position of most significant bits are explicitly maintained across the transport for the STM-TC stream. The STM-TC stream is presented synchronously across the γ_R or γ_O reference point with respect to the synchronization signals across the α/β interface.

Support for a plesiochronous interface is under study.

L.1.2 References

This clause is intentionally blank because there are no STM-TC specific references.

L.1.3 Definitions

This clause is intentionally blank because there are no STM-TC specific definitions.

L.1.4 Abbreviations

This clause is intentionally blank because there are no STM-TC specific abbreviations.

L.1.5 Transport capabilities

The STM-TC function provides procedures for the transport of one STM-TC stream in either the upstream and downstream direction. Octet boundaries and the position of most significant bits shall be explicitly maintained across the transport for the STM-TC stream. The STM-TC stream is presented synchronously across the γ_R or γ_O reference point with respect to the PMD bit clocks.

After each of the transmit STM-TC procedures has been applied, transport of the STM-TC stream to a receive STM-TC function at the other end of the link is carried out by underlying PMS-TC and PMD layers through a series of data frames and PMD symbols. The STM-TC transport capabilities are configured by control parameters described in clause L.1.7. The control parameters provide for the application of appropriate data rates and characteristics of the STM-TC stream. The values of all control parameters are set during initialization or reconfiguration of the VTU. The receive STM-TC function recovers the input signal that was presented to the corresponding transmit STM-TC function and which has been transported across the STM-TC, PMS-TC, and PMD functions of a VTU-O and VTU-R pair.

The transmit STM-TC function accepts input signals from the data plane and control plane within the VTU. As a data plane element, the transmit STM-TC function accepts one STM-TC stream from the γ_O or γ_R reference points. The stream is associated with one, and only one, STM-TC function. These input signals are conveyed to the receive STM-TC interface as shown in Figure L.1. Octet boundaries and the position of most significant bits are explicitly maintained across the transport for the STM-TC frame bearers.

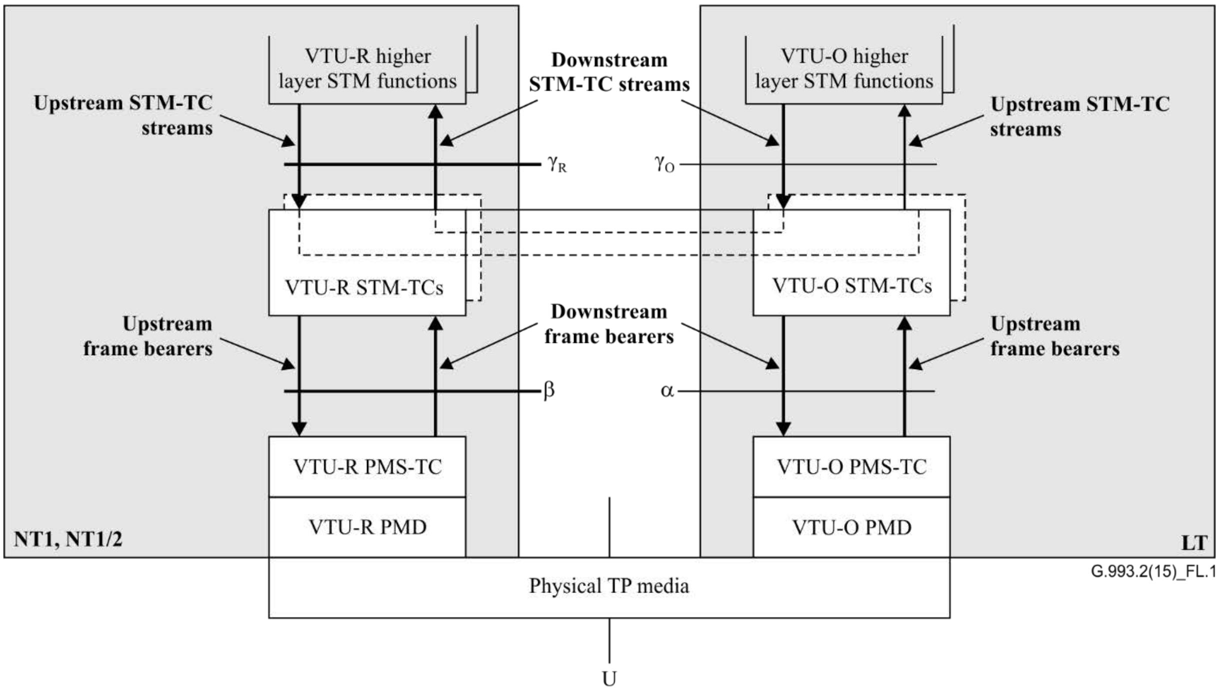

Figure L.1 – STM-TC transport capabilities within the user plane

As a management plane element, there are no specific transport functions provided by the STM-TC function. However, there are some specific indicator bits and overhead response definitions for the STM-TC function as defined in this annex.

L.1.6 Interface primitives

Each VTU-O STM-TC function has many interface signals as shown in Figure L.2. Each named signal is composed of one or more primitives, as denoted by the directional arrows. The primitive type associated with each arrow is according to the figure legend.

The diagram is divided by a dotted line to separate the downstream function and signals from the upstream. The signals shown at the top edge convey primitives to and from the higher layer STM function. The signals shown at the bottom edge convey primitives to and from the PMS-TC function.

Each VTU-R STM-TC function has similar interface signals as shown in Figure L.3. In this figure, the upstream and downstream labels are reversed from Figure L.1.

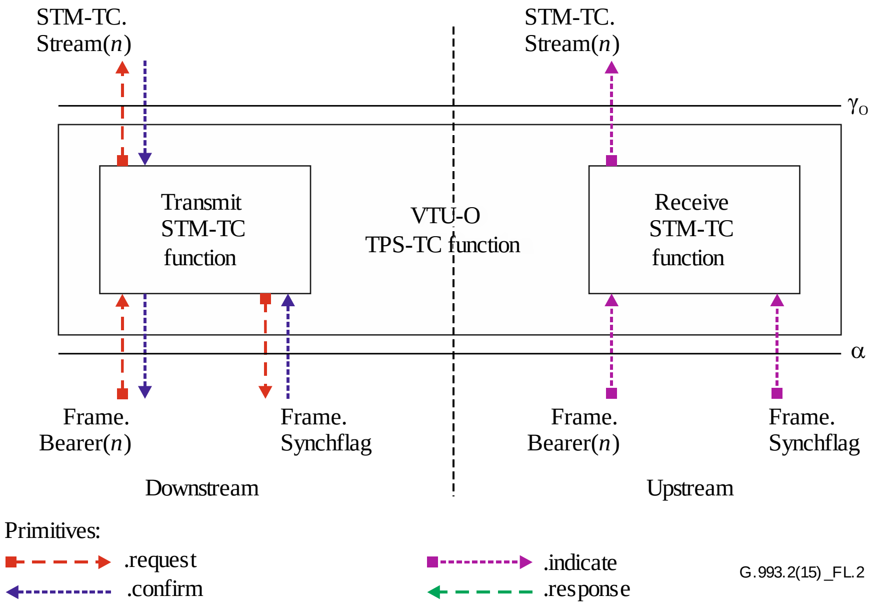

Figure L.2 – Signals of the VTU-O STM-TC function

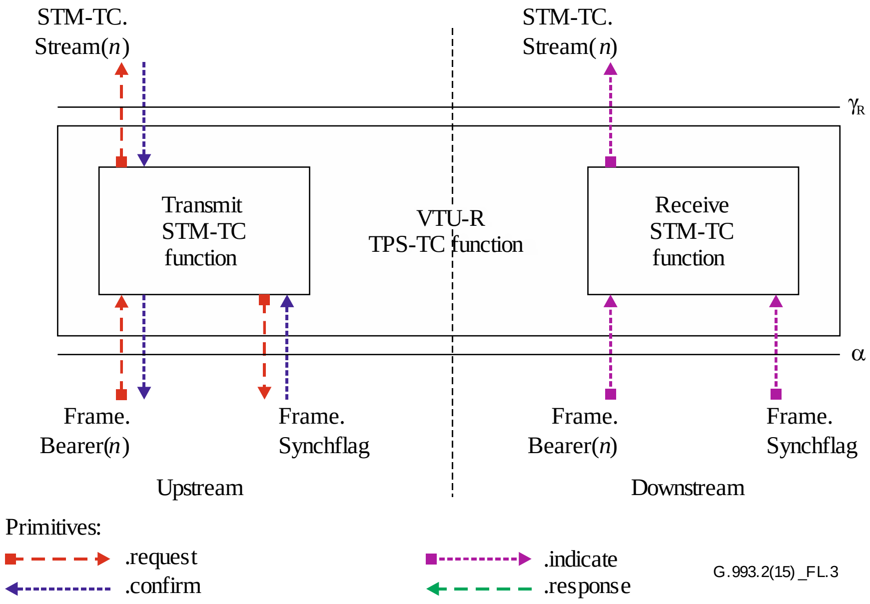

Figure L.3 – Signals of the VTU-R STM-TC function

The signals shown in Figures L.2 and L.3 are used to carry primitives between functions of this Recommendation. Primitives are only intended for purposes of clearly specifying functions to assure interoperability.

The primitives that are used between a higher layer STM function and STM-TC function are described in Table L.1. These primitives support the exchange of frame bearer data and regulation of data flow to match the PMS-TC configuration. They also support coordinated on-line reconfiguration of the VTU-O and VTU-R.

Table L.1 – Signalling primitives between STM higher layer functions and the STM-TC function

Signal	Primitive	Description
TPS-TC.Stream(*n*).STM	.request	This primitive is used by the transmit STM-TC function to request one or more octets from the transmit higher layer STM function to be transported. By the interworking of the request and confirm, the data flow is matched to the STM-TC configuration (and underlying functions). Primitives are labelled *n*, where *n* corresponds to the TPS-TC function id (e.g., $n = 0$ for TPS-TC #0).
	.confirm	The transmit higher layer STM function passes one or more octets to the STM-TC function to be transported with this primitive. Upon reception of this primitive, the STM-TC function shall perform the data plane procedures in clause L.1.8.
	.indicate	The receive STM-TC function passes one or more octets that have been transported with this primitive to the receive higher layer STM function.

L.1.7 Control parameters

The configuration of the STM-TC function is controlled by a set of control parameters defined in Table L.2 in addition to those specified in the main body of this Recommendation. The values of these control parameters shall be set and communicated during initialization or reconfiguration (if applicable) of a VTU pair. All the values are determined by application requirements and means that are beyond the scope of this Recommendation.

Table L.2 – STM-TC parameters

Parameter	Definition
Minimum net data rate net_min_n	The minimum net data rate supported by the STM-TC stream #*n*. The VTU shall implement appropriate initialization and reconfiguration procedures to provide net_min_n data rate.
Maximum net data rate net_max_n	The maximum net data rate supported by STM-TC stream #*n*. During initialization and reconfiguration procedures, the net data rate shall not exceed this value.
Minimum SOS net data rate $MIN\text{-}SOS\text{-}BR_n$	The minimum net data rate required by the STM-TC stream #*n* for a valid SOS request (see clause 13.4).
Minimum reserved data rate $net\_reserve_n$	The minimum reserved data rate supported by STM-TC stream #*n* that shall always be available upon request by an appropriate reconfiguration procedure. The value of $net\_reserve_n$ shall be constrained such that $net\_min_n \leq net\_reserve_n \leq net\_max_n$. This parameter is not used in this version of this Recommendation and shall be set to net_min_n. The OLR procedures that utilize this parameter will be defined in a future revision of this Recommendation.
Maximum PMS-TC latency $delay\_max_n$	The STM-TC stream #*n* shall be transported with underlying PMS-TC functions configured such that the derived parameter $delay_p$ is no larger than this control parameter $delay\_max_n$.
Minimum PMS-TC impulse noise protection INP_min_n	The STM-TC stream #*n* shall be transported with underlying PMS-TC functions configured such that the derived parameter INP_p is not lower than this control parameter INP_min_n.

Table L.2 – STM-TC parameters

Parameter	Definition
Channel initialization policy $CIpolicy_n$	This parameter controls the policy to be applied in setting the transceiver configuration parameters during initialization (see clause 12.3.7).
Maximum delay variation DV_max_n	The STM-TC stream #n shall be transported with underlying PMS-TC OLR function as defined in clause 13.4 such that the derived parameter DV_p is not lower than this control parameter DV_max_n.

If the values of net_min_n, net_max_n, and $net\_reserve_n$ (see Table 12-54) are set to the same value, then the STM-TC stream is designated as a fixed data rate STM-TC stream (i.e., RA-MODE = MANUAL, see Table 12-49). If $net\_min_n = net\_reserve_n$ and $net\_min_n \neq net\_max_n$, then the STM-TC stream is designated as a flexible data rate STM-TC stream. If the value of $net\_min_n \neq net\_max_n \neq net\_reserve_{max}$, then the STM-TC stream is designated as a flexible data rate STM-TC stream with reserved data rate allocation.

During initialization and reconfiguration procedures (except SOS), the actual net data rate net_act_n for stream #*n* shall always be set to the value of the derived parameter NDR_{pn} of the underlying PMS-TC latency path function and shall be constrained such that $net\_min_n \leq net\_act_n \leq net\_max_n$. However, in case the $net\_min_n = net\_max_n$, the net_act_n may exceed the net_max_n by up to 8 kbit/s, to allow for the PMS-TC net data rate granularity (see Table 5-1). If $net\_min_n < net\_max_n$, the net_max_n shall be set at least 8 kbit/s above the net_min_n, to allow for the PMS-TC net data rate granularity to meet the $net\_min_n \leq net\_act_n \leq net\_max_n$ requirement. The actual latency for the stream #*n*, $delay\_act_n$ shall always be set to the value of the derived parameter $delay_p$ of the underlying PMS-TC latency path function and constrained such that $delay\_act_n \leq delay\_max_n$.

The actual impulse noise protection, INP_act_n, of transport of stream #*n* shall always be set to the value of the derived parameter INP_p of the underlying PMS-TC path function and constrained such that $INP\_act_n \geq INP\_min_n$. The values net_act_n, $delay\_act_n$ and INP_act_n are not control parameters; these values are the result of specific initialization and reconfiguration procedures.

During SOS reconfiguration procedures, the net data rates, INP and delay shall comply with clause 13.4.

L.1.7.1 Valid configurations

The configurations listed in Table L.3 are valid for the STM-TC function.

Table L.3 – Valid configuration for STM-TC function

Parameter	Capability
$type_n$	1
net_min_n	net_min_n may be supported for all valid framing configurations.
net_max_n	net_max_n may be supported for all valid framing configurations.
$net\_reserve_n$	$net\_reserve_n$ may be supported for all valid framing configurations.
$MIN\text{-}SOS\text{-}BR_n$	$MIN\text{-}SOS\text{-}BR_n$ may be supported for all valid framing configurations.
$delay\_max_n$	All valid values of $delay\_max_n$ (see Table 12-51).
INP_min_n	All valid values of INP_min_n (Table 12-51).
$CIpolicy_n$	0, 1, 2

L.1.7.2 Mandatory configurations

If implementing a STM-TC, a VTU shall support all combinations of the values of STM-TC control parameters for a STM-TC function displayed in Tables L.4 and L.5 in the downstream and upstream directions, respectively. The transmitter and receiver shall support mandatory features displayed in these tables, and in Table L.6.

Table L.4 – Mandatory downstream configuration for STM-TC function

Parameter	Capability
$type_n$	1
$delay\_max_n$	All valid values shall be supported.
INP_min_n	All valid values shall be supported.
$CIpolicy_n$	0

Table L.5 – Mandatory upstream configuration for STM-TC function

Parameter	Capability
$type_n$	1
$delay\_max_n$	All valid values shall be supported.
INP_min_n	All valid values shall be supported.
CIpolicy	0

Table L.6 – Mandatory bidirectional configuration for STM-TC function

Parameter	Capability
bi_net_min	*bi_net_min* shall be supported for all valid framing configurations up to and equal to the MBDC defined in clause 6.2.7 for the applicable profile.
bi_net_max	*bi_net_max* shall be supported for all valid framing configurations up to and equal to the MBDC defined in clause 6.2.7 for the applicable profile.
bi_net_reserve	*bi_net_reserve* shall be supported for all valid framing configurations up to and equal to the MBDC defined in clause 6.2.7 for the applicable profile.

L.1.8 Data plane procedures

Upon reception of the Frame.Bearer.request(*n*) primitive, the transmit STM-TC function shall signal a TPS-TC.Stream.STM.request to the STM higher layer function, requesting data for transport.

Upon reception of a TPS-TC.STM.confirm(*n*) primitive, the receive STM-TC function #*n* shall signal a Frame.Bearer(*n*).confirm primitive to the PMS-TC function, providing data for transport.

Upon reception of the Frame.Bearer.indicate(*n*) primitive, the receive STM-TC function #*n* shall signal a TPS-TC.Stream.STM.indicate to the STM higher layer function, providing data that has been transported.

L.1.9 Management plane procedures

L.1.9.1 Surveillance primitives

Surveillance primitives for the STM-TC function are under study.

L.1.9.2 Indicator bits

The indicator bits for TPS-TC #*n* and bearer channel #*n* (*n* = 0 or 1) are defined in clause 9.5.2.2. The TIB#*n*-0, TIB#*n*-1, TIB#*n*-2 and TIB#*n*-3 shall be set to a 1 for use in Table 9-5.

L.1.9.3 Overhead command formats

L.1.9.3.1 Inventory command

For further study.

L.1.9.3.2 Control value read command

For further study.

L.1.9.3.3 Management Counter Read command

The TPS-TC octets in the response to the overhead Management Counter Read command corresponding to the STM-TC function are under study. The block of counter values corresponding to the STM-TC function returned in the message described in Table 11-18 shall have zero length.

L.1.10 Initialization procedure

The STM-TC shall be configured during initialization as follows:

- During the channel analysis and exchange phase (see clause 12.3.5.2.1), the VTU-O uses the O-MSG 1 SOC message (see Table 12-49) to convey its upstream and downstream TPS-TC capabilities and bearer control parameters (see Table L.2) to the VTU-R;
- During the channel analysis and exchange phase (see clause 12.3.5.2.1), the VTU-R uses the R-MSG 2 SOC message (see Table 12-60) to convey its upstream and downstream TPS-TC capabilities and bearer control parameters (see Table L.2) to the VTU-O;
- During the channel analysis and exchange phase (see clause 12.3.5.2.1.2), the VTU-O uses the O-TPS SOC message (see Table 12-53) to convey the upstream and downstream TPS-TC configuration to the VTU-R. It is based on the capabilities that were indicated in O-MSG 1 and R-MSG 2.

L.1.11 On-line reconfiguration

The on-line reconfiguration of the STM-TC is outside the scope of this Recommendation. There is no specified mechanism to modify the value of the control parameters of the STM-TC function. The values of *net_act* and *delay_act* are automatically updated from the underlying PMS-TC latency path function.

L.1.11.1 Changes to an existing stream

Update of the *net_act* and *delay_act* parameters of an existing STM-TC function shall only occur at octet boundaries. The transmit STM-TC function uses the new values of the *net_act*, and *delay_act* to generate octets that follow the signalling of the Frame.Synchflag.confirm primitive. The receive STM-TC function procedures process octets that follow the signalling of the Frame.Synchflag.indicate primitive using the new values of these parameters.

L.2 ATM transmission convergence (ATM-TC) function

L.2.1 Scope

The ATM-TC function provides procedures for the transport of one ATM-TC stream in either the upstream or downstream direction. Octet boundaries and the position of most significant bits are explicitly maintained across the transport for the ATM-TC stream. The ATM-TC stream is presented asynchronously across the γ_R or γ_O reference point with respect to the synchronization signals across the α/β interface.

L.2.2 References

References applicable to this annex are included in clause 2.

L.2.3 Definitions

This clause is intentionally blank because there are no ATM-TC specific definitions.

L.2.4 Abbreviations

Abbreviations applicable to this annex are included in clause 4.

L.2.5 Transport capabilities

The ATM-TC function provides procedures for the transport of one ATM-TC stream in either the upstream or downstream direction. Octet boundaries and the position of most significant bits shall be explicitly maintained across the transport for the ATM-TC stream. The ATM-TC stream is presented asynchronously across the γ_R or γ_O reference point with respect to the PMD bit clocks.

After each of the transmit ATM-TC procedures has been applied, transport of the ATM-TC stream to a receive ATM-TC function at the other end of the link is carried out by underlying PMS-TC and PMD layers through a series of data frames and PMD symbols. The ATM-TC transport capabilities are configured by control parameters described in clause L.2.7. The control parameters provide for the application appropriate data rates and characteristics of the ATM-TC stream. The values of all control parameters are set during initialization or reconfiguration of the VTU. The receive ATM-TC function recovers the input signal that was presented to the corresponding transmit ATM-TC function and which has been transported across the ATM-TC, PMS-TC and PMD functions of an VTU-O and VTU-R pair.

The transmit ATM-TC function accepts input signals from the data plane and control plane within the VTU. As a data plane element, the transmit ATM-TC function accepts one ATM-TC stream from the γ_O or γ_R reference points. The stream is associated with one, and only one, ATM-TC function. These input signals are conveyed to the receive ATM-TC interface as shown in Figure L.4. Octet boundaries and the position of most significant bits are explicitly maintained across the transport for the ATM-TC frame bearers.

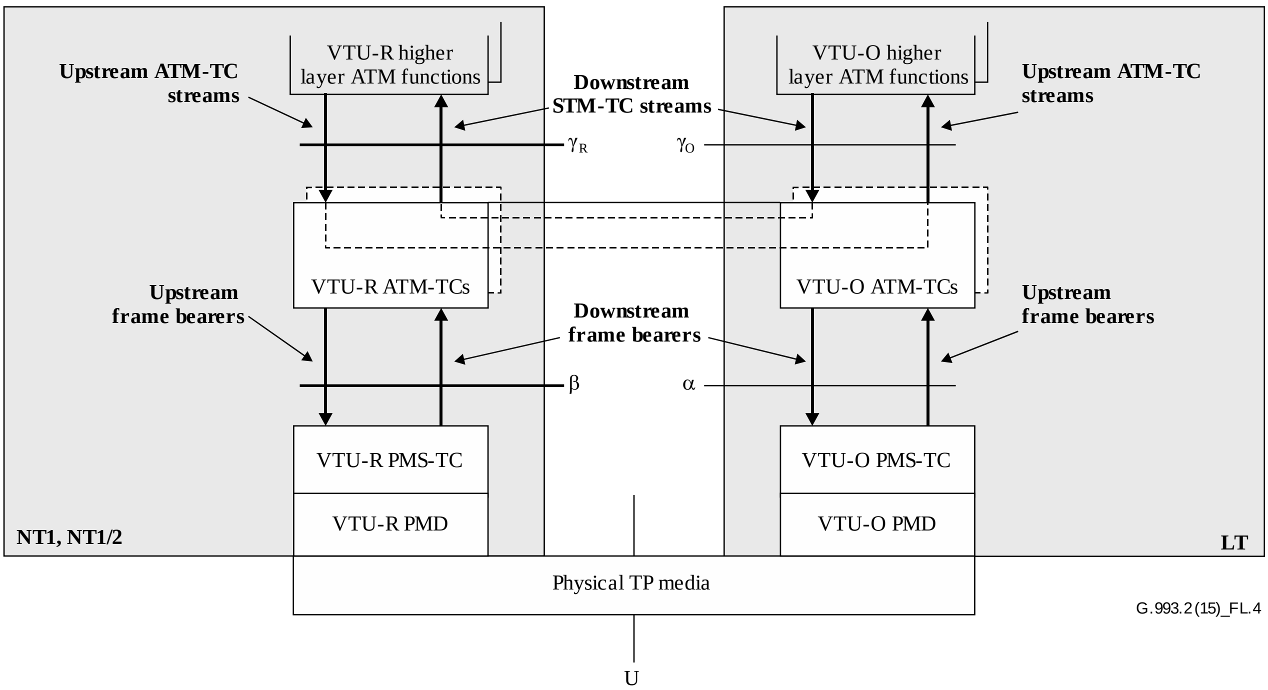

Figure L.4 – ATM-TC transport capabilities within the user plane

As a management plane element, there are no specific transport functions provided by the ATM-TC function. However, there are some specific indicator bit and overhead response definitions for the ATM-TC function as defined in this annex.

L.2.5.1 Additional functions

In addition to transport functions, the transmit ATM-TC function also provides procedures for rate decoupling of the ATM-TC stream and the frame bearer by ATM idle cell insertion, ATM header error control generation, and scrambling, as described in clause L.2.8.

The receive ATM-TC function reverses each of the listed procedures so that the transported information may be recovered. Additionally, the VTU receive framing function provides several supervisory indications and defect signals associated with some of these procedures (e.g., ATM cell delineation status, HEC error check failure).

L.2.6 Interface primitives

Each VTU-O ATM-TC function has many interface signals as shown in Figure L.5. Each named signal is composed of one or more primitives, as denoted by the directional arrows. The primitive type associated with each arrow is according to the figure legend.

The diagram is divided by a dotted line to separate the downstream function and signals from the upstream. The signals shown at the top edge convey primitives to and from the higher layer ATM function. The signals shown at the bottom edge convey primitives to and from the PMS-TC function.

Each VTU-R ATM-TC function has similar interface signals as shown in Figure L.6. In this figure, the upstream and downstream labels are reversed from Figure L.5.

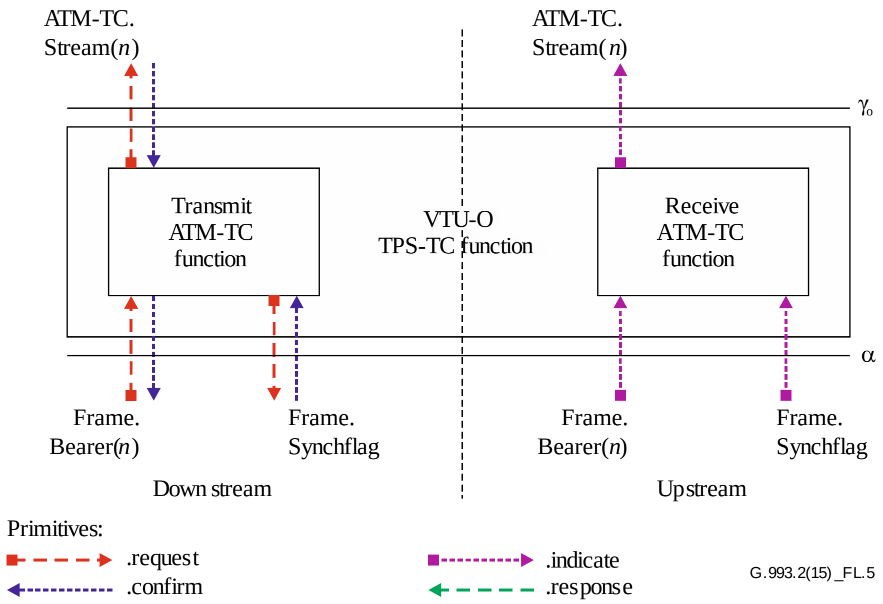

Figure L.5 – Signals of the VTU-O ATM-TC function

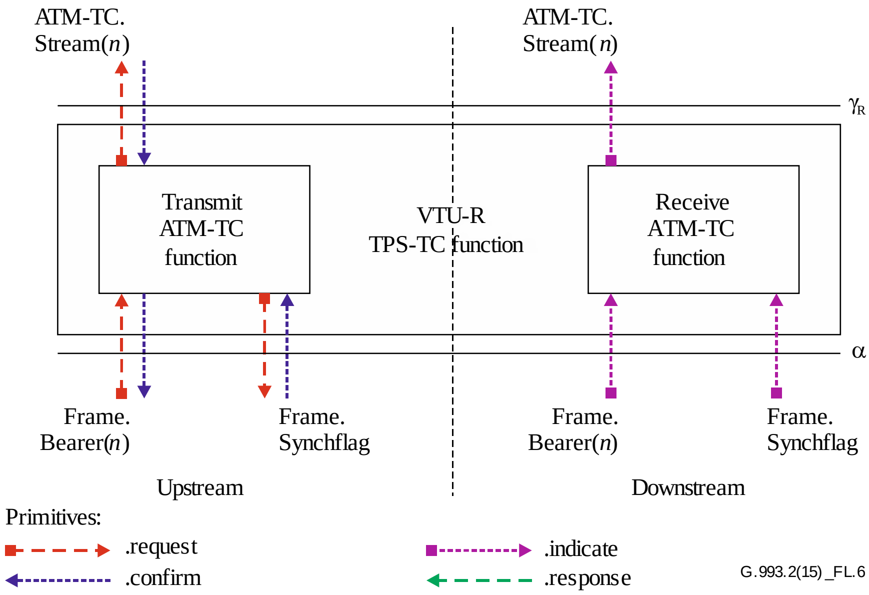

Figure L.6 – Signals of the VTU-R ATM-TC function

The signals shown in Figures L.5 and L.6 are used to carry primitives between functions of this Recommendation. Primitives are only intended for purposes of clearly specifying functions to assure interoperability.

The primitives that are used between a higher layer ATM function and ATM-TC function are described in Table L.7. These primitives support the exchange of stream and frame bearer data and regulation of data flow to match the PMS-TC configuration. They also support coordinated on-line reconfiguration of the VTU-O and VTU-R.

Table L.7 – Signalling primitives between ATM higher layer functions and the ATM-TC function

Signal	Primitive	Description
TPS-TC.Stream(*n*).ATM	.request	This primitive is used by the transmit ATM-TC function to request one or more ATM cells from the transmit higher layer ATM function to be transported. By the interworking of the request and confirm, the data flow is matched to the ATM-TC configuration (and underlying functions). Primitives are labelled *n*, where *n* corresponds to the TPS-TC function id (e.g., *n* = 0 for TPS-TC #0).
	.confirm	The transmit higher layer ATM function passes one or more ATM cells to the ATM-TC function to be transported with this primitive. Upon reception of this primitive, the ATM-TC function shall perform the procedures in L.2.8.2.
	.indicate	The receive ATM-TC function passes one or more ATM cells to the receive higher layer ATM function that have been transported with this primitive.

L.2.7 Control parameters

The configuration of the ATM-TC function is controlled by a set of control parameters defined in Table L.8 in addition to those specified in the main body of this Recommendation. The values of these control parameters shall be set and communicated during initialization or reconfiguration (if applicable) of a VTU pair. All the values are determined by application requirements and means that are beyond the scope of this Recommendation.

Table L.8 – ATM-TC parameters

Parameter	Definition
Minimum net data rate net_min_n	The minimum net data rate supported by the ATM-TC stream #*n*. The VTU shall implement appropriate initialization and reconfiguration procedures to provide net_min_n data rate.
Maximum net data rate net_max_n	The maximum net data rate supported by ATM-TC stream #*n*. During activation and reconfiguration procedures, the net data rate shall not exceed this value.
Minimum SOS net data rate $MIN\text{-}SOS\text{-}BR_n$	The minimum net data rate required by the ATM-TC stream #*n* for a valid SOS request (see clause 13.4).
Minimum reserved data rate $net\_reserve_n$	The minimum reserved data rate supported by ATM-TC stream #*n* that shall always be available upon request by an appropriate reconfiguration procedure. The value of $net\_reserve_n$ shall be constrained such that $net\_min_n \leq net\_reserve_n \leq net\_max_n$. This parameter is not used in this version of this Recommendation and shall be set to net_min_n. The OLR procedures that utilize this parameter will be defined in a future revision of this Recommendation.
Maximum PMS-TC latency $delay\_max_n$	The ATM-TC stream #*n* shall be transported with underlying PMS-TC functions configured such that the derived parameter $delay_p$ is no larger than this control parameter $delay\_max_n$.
Minimum PMS-TC impulse noise protection INP_min_n	The ATM-TC stream #*n* shall be transported with underlying PMS-TC functions configured such that the derived parameter INP_p is not lower than this control parameter INP_min_n.
Channel initialization policy $CIpolicy_n$	This parameter controls the policy to be applied in setting the transceiver configuration parameters during initialization (see clause 12.3.7).
Maximum delay variation DV_max_n	The ATM-TC stream #n shall be transported with underlying PMS-TC OLR function as defined in clause 13.4 such that the derived parameter DV_p is not lower than this control parameter DV_max_n.

If the values of net_min_n, net_max_n, and $net\_reserve_n$ (see Table 12-54) are set to the same value, then the ATM-TC stream is designated as a fixed data rate ATM-TC stream (i.e., RA-MODE = MANUAL, see Table 12-49). If $net\_min_n = net\_reserve_n$ and $net\_min_n \neq net\_max_n$, then the ATM-TC stream is designated as a flexible data rate ATM-TC stream. If the value of $net\_min_n \neq net\_max_n \neq net\_reserve_{max}$, then the ATM-TC stream is designated as a flexible data rate ATM-TC stream with reserved data rate allocation.

During initialization and reconfiguration procedures (except SOS), the actual net data rate net_act_n for stream #*n* shall always be set to the value of the derived parameter NDR_{pn} of the underlying PMS-TC latency path function and shall be constrained such that $net\_min_n \leq net\_act_n \leq net\_max_n$. However, in case the $net\_min_n = net\_max_n$, the net_act_n may exceed the net_max_n by up to 8 kbit/s, to allow for the PMS-TC net data rate granularity (see Table 5-1). If $net\_min_n < net\_max_n$, the net_max_n shall be set at least 8 kbit/s above the net_min_n, to allow for the PMS-TC net data rate granularity to meet the $net\_min_n \leq net\_act_n \leq net\_max_n$ requirement. The actual latency $delay\_act_n$ of transport of stream #*n* shall always be set to the value of the derived parameter $delay_p$ of the underlying PMS-TC path function and constrained such that $delay\_min_n \leq delay\_act_n \leq delay\_max_n$. The values net_act_n and $delay\_act_n$ are not control parameters; these values are the result of specific initialization and reconfiguration procedures.

If ATM bonding is not set in the ITU-T G.994.1 bonding code tree, $delay\_min_n$ shall be set to ZERO both upstream and downstream, and $delay\_max_n$ can be set to any valid value. If ATM bonding is set, then the ITU-T G.994.1 bonding code tree includes the value of the *max_delay_variation* control parameter for downstream ATM bonding and the $delay\_min_n$ shall be set to $delay\_max_n - max\_delay\_variation$ for the downstream direction. If information related to $delay\_min_n$ is available through the VTU-R bonding management interface over the γ_R reference point, it may take precedence over the value derived from the ITU-T G.994.1 bonding code tree. For the upstream direction, the information related to $delay\_min_n$ is available through the VTU-O bonding management interface over the γ_O reference point. For both upstream and downstream, if $delay\_min_n$ is greater than 0, there are combinations of $delay\_min_n$ and $delay\_max_n$ that may result in a failure to connect.

The actual impulse noise protection of the stream #*n*, INP_act_n of transport of stream #*n*, shall always be set to the value of the derived parameter INP_p of the underlying PMS-TC path function and constrained such that $INP\_act_n \geq INP\_min_n$. The values net_act_n, $delay\_act_n$ and INP_act_n are not control parameters; these values are the result of specific initialization and reconfiguration procedures.

During SOS reconfiguration procedures, the net data rates, INP and delay shall comply with clause 13.4.

L.2.7.1 Valid configurations

The configurations listed in Table L.9 are valid for the ATM-TC function.

Table L.9 – Valid configuration for ATM-TC function

Parameter	Capability
$type_n$	2
net_min_n	net_min_n may be supported for all valid framing configurations.
net_max_n	net_max_n may be supported for all valid framing configurations.
$net\_reserve_n$	$net\_reserve_n$ may be supported for all valid framing configurations.
$MIN\text{-}SOS\text{-}BR_n$	$MIN\text{-}SOS\text{-}BR_n$ may be supported for all valid framing configurations.
$delay\_max_n$	All valid values of $delay\_max_n$ (see Table 12-51).
INP_min_n	All valid values of INP_min_n (see Table 12-51).
$CIpolicy_n$	0, 1, 2

L.2.7.2 Mandatory configurations

If implementing an ATM-TC, a VTU shall support all combinations of the values of ATM-TC control parameters for ATM-TC function #0 displayed in Tables L.10 and L.11 in the downstream and upstream directions, respectively. The transmitter and receiver shall support mandatory features displayed in these tables, and in Table L.12.

Table L.10 – Mandatory downstream configuration for ATM-TC function #0

Parameter	Capability
$type_n$	2
$delay\_max_n$	All valid values shall be supported.
INP_min_n	All valid values shall be supported.
$CIpolicy_n$	0

Table L.11 – Mandatory upstream configuration for ATM-TC function #0

Parameter	Capability
$type_n$	2
$delay\_max_n$	All valid values shall be supported.
INP_min_n	All valid values shall be supported.

Table L.12 – Mandatory bidirectional configuration for ATM-TC function

Parameter	Capability
bi_net_min	*bi_net_min* shall be supported for all valid framing configurations up to and equal to the MBDC defined in clause 6.2.7 for the applicable profile.
bi_net_max	*bi_net_max* shall be supported for all valid framing configurations up to and equal to the MBDC defined in clause 6.2.7 for the applicable profile.
bi_net_reserve	*bi_net_reserve* shall be supported for all valid framing configurations up to and equal to the MBDC defined in clause 6.2.7 for the applicable profile.

L.2.8 Data plane procedures

L.2.8.1 Block diagram

Figure L.7 shows the functions within a transmit ATM-TC function that supports one unidirectional ATM-TC stream and one frame bearer. The incoming ATM-TC stream is shown at the leftmost edge of Figure L.7. The output signal from the ATM-TC function forms a frame bearer (i.e., input to the transmit PMS-TC function), and is shown at the rightmost edge of Figure L.7.

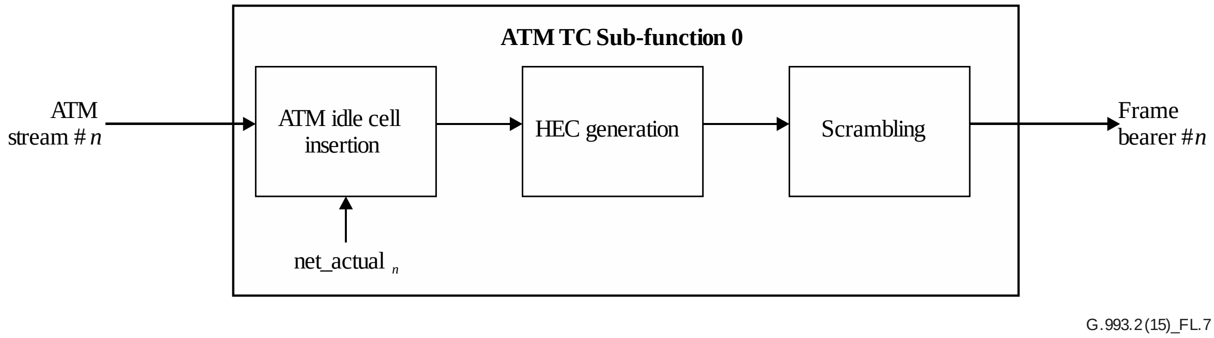

Figure L.7 – Block diagram of transmit ATM-TC function

In the ATM-TC stream and within the ATM-TC function, data octets shall be transmitted MSB first in accordance with [ITU-T I.361] and [ITU-T I.432.1]. All serial procedures within the ATM-TC function shall begin MSB first. Below the α and β interfaces of the VTU (starting with the Frame.Bearer primitives), data octets shall be transported LSB first. As a result, the MSB of the first octet of the first ATM-TC.Stream(*n*).confirm primitive will be the LSB of the first octet of the first Frame.Bearer(*n*).confirm primitive. The labelling of bits within the ATM-TC layer and at the frame bearer is shown in Figure L.8.

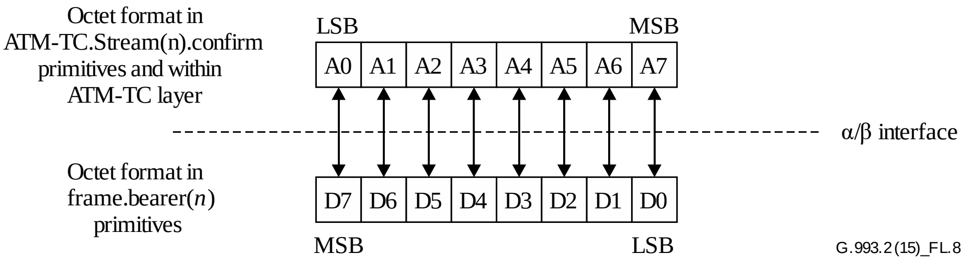

Figure L.8 – Bit mapping of the user plane transport function of the ATM-TC function

L.2.8.2 Rate matching by idle cell insertion

ATM idle cells shall be inserted by the transmit function to provide ATM cell rate decoupling. ATM idle cells shall not be delivered to higher layer functions by the receive ATM-TC functions.

ATM idle cells are identified by the standardized pattern for the cell header given in [ITU-T I.432.1].

L.2.8.3 HEC octet

The transmit ATM-TC function shall generate an HEC octet as described in [ITU-T I.432.1], including the recommended modulo 2 addition (XOR) of the binary pattern 01010101 to the HEC bits.

The HEC covers the entire cell header. The generator polynomial coefficient set used and the HEC sequence generation procedure shall be in accordance with [ITU-T I.432.1].

L.2.8.4 Cell delineation

The receiver ATM-TC function shall perform cell delineation. The cell delineation procedure permits the identification of ATM cell boundaries in the Frame.Bearer.indicate primitives. The procedure uses the HEC field in the cell header. Cell delineation shall be performed using a coding law by checking the HEC field in the cell header according to the algorithm described in [ITU-T I.432.1]. The cell delineation procedure is shown as a state machine in Figure L.9. Each state is described in Table L.13.

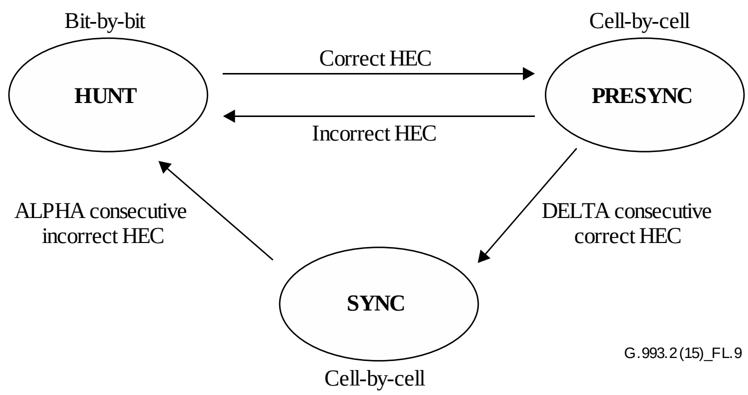

Figure L.9 – Cell delineation procedure state machine

Table L.13 – ATM cell delineation procedure states

State	Definition
HUNT	In the HUNT state, the cell delineation procedure may either be performed by checking bit-by-bit or octet-by-octet for the correct HEC. Once such an agreement is found, it is assumed that one header has been found, and the procedure enters the PRESYNC state. When octet boundaries are available, the cell delineation procedure may be performed octet-by-octet.
PRESYNC	In the PRESYNC state, the cell delineation procedure shall be performed by checking cell-by-cell for the correct HEC. If the correct HEC has been confirmed DELTA times consecutively, the procedure enters the SYNC state. If an incorrect HEC is found, the procedure returns to the HUNT state.
SYNC	In the SYNC state the cell delineation procedure shall return to the HUNT state if an incorrect HEC is obtained ALPHA times consecutively.

Specific values of ALPHA and DELTA are vendor discretionary, because the choice of these values is not considered to affect interoperability.

NOTE – The use of the values suggested in [ITU-T I.432.1] (ALPHA = 7, DELTA = 6) may be inappropriate due to the VTU transport characteristics.

L.2.8.5 ATM cell error detection

The receiver ATM-TC function shall implement error detection over the entire cell header as defined in [ITU-T I.432.1]. The code specified in [ITU-T I.432.1] is capable of single bit error correction and multiple bit error detection. However, HEC error correction shall not be implemented by the VTU, and any HEC error shall be considered as a multiple bit error.

ATM cells detected to be in error shall not be passed in a TPS-TC.Stream(*n*).ATM.indicate primitive.

L.2.8.6 Scrambler

The transmit ATM-TC function shall scramble the cell payload field to improve the security and robustness of the cell delineation mechanism. The self-synchronizing scrambler uses the polynomial $X^{43} + 1$. The scrambler procedures defined in [ITU-T I.432.1] shall be implemented.

L.2.9 Management plane procedures

L.2.9.1 Surveillance primitives

The ATM-TC function surveillance primitives are ATM path related. Both anomalies and defects are defined for each receiver ATM-TC function.

Three near-end anomalies are defined as follows:

1) No Cell Delineation (*ncd-n*) anomaly: An *ncd-n* anomaly occurs immediately after receiving the first Frame.Bearer(*n*).indicate primitive. The anomaly terminates when the cell delineation process of the receive ATM-TC function #*n* transitions to the SYNC state. Once cell delineation is acquired, subsequent losses of cell delineation shall be considered as *ocd-n* anomalies;
2) Out of Cell Delineation (*ocd-n*) anomaly: An *ocd-n* anomaly occurs when the cell delineation process of receive ATM-TC subfunction #*n* transitions from the SYNC state to the HUNT state. An *ocd-n* anomaly terminates when the cell delineation process transitions from PRESYNC state to SYNC state or when the *lcd-n* is asserted;
3) Header Error Check (*hec-n*) anomaly: A *hec-n* anomaly occurs each time the ATM cell header process of receiver ATM-TC function #*n* detects an error.

These near-end anomalies are counted locally per [ITU-T G.997.1]. The values of the counter may be read or reset via local commands not defined in this Recommendation.

Three far-end anomalies are defined as follows:

1) Far-end No Cell Delineation (*fncd-n*) anomaly: An *fncd-n* anomaly is an *ncd-n* anomaly detected at the far end;
2) Far-end Out of Cell Delineation (*focd-n*) anomaly: An *focd-n* anomaly is an *ocd-n* anomaly detected at the far end;
3) Far-end Header Error Check (*fhec-n*) anomaly: An *fhec-n* anomaly is a *hec-n* anomaly detected at the far end.

These far-end anomalies are not individually observable. The count of these far-end anomalies may be read and reset via overhead commands defined in clause 11.2.3.7. The format of the counters shall be as described in clause L.2.9.3.3.

One near-end defect is defined as follows:

1) Loss of cell delineation (*lcd-n*): This defect occurs when at least one *ocd-n* anomaly is present in each of four consecutive overhead frames and no *sef-n* is present. An *lcd-n* terminates when no *ocd-n* anomaly is present in four consecutive overhead frames.

This near-end defect is processed locally per [ITU-T G.997.1].

One far-end defect is defined as follows:

1) Far-end loss of cell delineation (*flcd-n*): This defect is an *lcd-n* detected at the far end.

This far-end defect is directly observed through an indicator bit as described in clause L.2.9.2.

L.2.9.2 Indicator bits

The indicator bits for TPS-TC #*n* and bearer channel #*n* (*n* = 0 or 1) are defined in clause 9.5.2.2.

The (logical OR of the) near-end defect *lcd-n* and the near-end anomalies *ncd-n* and *ocd-n* shall be mapped to the TPS-TC indicator TIB#*n*-0 and transported as described in Table 9-5. The bit shall be encoded as a 1 when inactive for use in Table 9-5.

The TIB#*n*-1, TIB#*n*-2 and TIB#*n*-3 shall be set to a 1 for use in Table 9-5.

NOTE – The TIB#*n*-0 corresponds to the NCD indicator bit defined in [ITU-T G.992.1].

L.2.9.3 Overhead command formats

L.2.9.3.1 Inventory command

For further study.

L.2.9.3.2 Control Value Read command

For further study.

L.2.9.3.3 Management Counter Read command

The TPS-TC management counters in the response to the overhead Management Counter Read command corresponding to the ATM-TC function shall be provided as defined in [ITU-T G.997.1]. The block of counter values corresponding to the ATM-TC function returned in the message described in Table 11-17 shall be as described in Table L.14.

Table L.14 – ATM-TC VTU management counter values

Length (Octets)	Octet number	Content
4	1 to 4	Counter of the HEC anomalies
4	5 to 8	Counter of total cells passed through HEC function
4	9 to 12	Counter of total cells passed to the upper layer ATM function
4	13 to 16	Counter of total bit errors detected in ATM idle cells payload

L.2.10 Initialization procedure

The ATM-TC shall be configured during initialization using the same procedure described in clause L.1.10.

L.2.11 On-line reconfiguration

The on-line reconfiguration of the ATM-TC is outside the scope of this Recommendation. There is no specified mechanism to modify the value of the control parameters of the ATM-TC function. The value of *net_act* and *delay_act* are automatically updated from the underlying PMS-TC latency path function.

L.2.11.1 Changes to an existing stream

Update of the *net_act* and *delay_act* parameters of an existing ATM-TC function shall only occur at octet boundaries. The transmit ATM-TC function uses the new values of the *net_act*, and *delay_act* to generate octets that follow the signalling of the Frame.Synchflag.confirm primitive. The receive ATM-TC function procedures process octets that follow the signalling of the Frame.Synchflag.indicate primitive using the new values of these parameters.

L.3 Packet transmission convergence function (PTM-TC)

L.3.1 Scope

The PTM-TC is intended for Ethernet transport and generic packet transport. The PTM-TC function provides procedures for the transport of one PTM-TC stream in either the upstream or downstream direction. Packet boundaries, octet boundaries, and the position of most significant bits are explicitly maintained across the transport for the PTM-TC stream. The PTM-TC stream is presented asynchronously across the γ_R or γ_O reference point with respect to the synchronization signals across the α/β interface.

The reference model, functionality, and γ interface of the PMS-TC are defined in Annex N of [ITU-T G.992.3]. Referring to the reference model of Annex N of [ITU-T G.992.3], the PTM-TC function of VDSL2 could be established over either of the enabled bearer channels.

L.3.2 References

References applicable to this annex are included in clause 2.

L.3.3 Definitions

This clause is intentionally blank because there are no PTM-TC specific definitions.

L.3.4 Abbreviations

Abbreviations applicable to this annex are included in clause 4.

L.3.5 Transport capabilities

The net data rate for each PTM-TC function, both upstream and downstream, may be set independently of each other, and to any eligible value that is less than or equal to the assigned maximum net data rate in the corresponding direction. The maximum net data rate for each PTM-TC function, both upstream and downstream, is set during the system configuration.
A PTM-TC function may be mapped to either enabled bearer channel, which in turn may or may not be interleaved.

The PTM-TC shall provide full transparent data transfer between γ_O and γ_R interfaces (except non-correctable errors in the PMD sublayer due to the noise in the loop). The PTM-TC shall provide packet integrity over the bearer channel that it is mapped to.

The PTM-TC transport capabilities are configured by control parameters described in clause L.3.7. The control parameters provide for the application appropriate data rates and characteristics of the PTM-TC stream. The values of all control parameters are set during initialization or reconfiguration of the VTU.

The transmit PTM-TC function accepts input signals from the data plane within the VTU. As a data plane element, the transmit PTM-TC function accepts one PTM-TC stream from a PTM entity across the γ_O or γ_R reference point. The stream is associated with one and only one PTM-TC function. (See Figure L.10.)

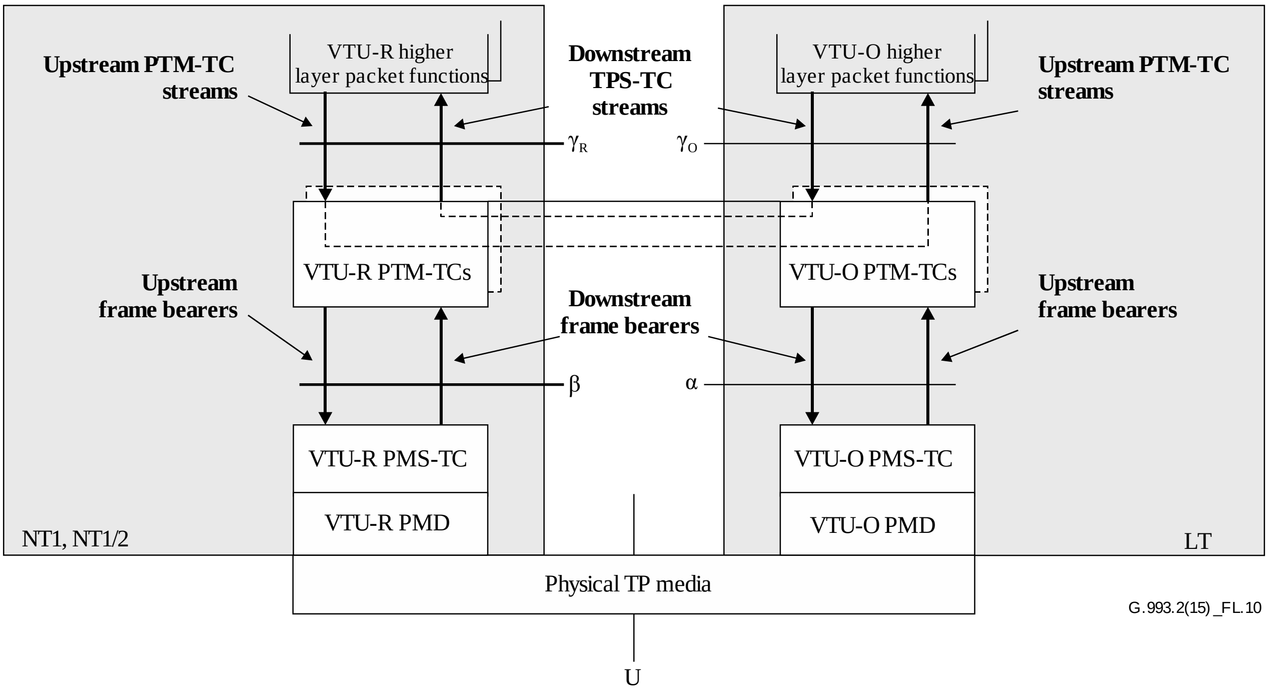

Figure L.10 – PTM-TC transport capabilities within the user plane

L.3.6 Interface primitives

The interface signals between the PTM-TC and PMS-TC (γ interface) are described in Annex N of [ITU-T G.992.3].

L.3.7 Control parameters

The configuration of the PTM-TC function is controlled by a set of control parameters defined in Table L.15 in addition to those specified in the main body of this Recommendation. The values of these control parameters shall be set and communicated during initialization or reconfiguration (if applicable) of a VTU pair. All the values are determined by application requirements and means that are beyond the scope of this Recommendation.

Table L.15 – PTM-TC parameters

Parameter	Definition
Minimum net data rate *net_min*$_n$	The minimum net data rate supported by the PTM-TC stream #*n*. The VTU shall implement appropriate initialization and reconfiguration procedures to provide *net_min*$_n$ data rate.
Maximum net data rate *net_max*$_n$	The maximum net data rate supported by PTM-TC stream #*n*. During initialization and reconfiguration procedures, the net data rate shall not exceed this value.
Minimum SOS net data rate *MIN-SOS-BR*$_n$	The minimum net data rate required by the PTM-TC stream #*n* for a valid SOS request (see clause 13.4).
Minimum reserved data rate *net_reserve*$_n$	The minimum reserved data rate supported by PTM-TC stream #*n* that shall always be available upon request by an appropriate reconfiguration procedure. The value of *net_reserve*$_n$ shall be constrained such that $net\_min_n \leq net\_reserve_n \leq net\_max_n$. This parameter is not used in this version of this Recommendation and shall be set to *net_min*$_n$. The OLR procedures that utilize this parameter will be defined in a future revision of this Recommendation.
Maximum PMS-TC latency *delay_max*$_n$	The PTM-TC stream #*n* shall be transported with underlying PMS-TC functions configured such that the derived parameter $delay_p$ is no larger than this control parameter *delay_max*$_n$.
Minimum PMS-TC impulse noise protection *INP_min*$_n$	The PTM-TC stream #*n* shall be transported with underlying PMS-TC functions configured such that the derived parameter INP_p is not lower than this control parameter *INP_min*$_n$.
Channel initialization policy *CIpolicy*$_n$	This parameter controls the policy to be applied in setting the transceiver configuration parameters during initialization (see clause 12.3.7).
Maximum delay variation *DV_max*$_n$	The PTM-TC stream #n shall be transported with underlying PMS-TC OLR function as defined in clause 13.4 such that the derived parameter DV_p is not lower than this control parameter *DV_max*$_n$.

If the values of *net_min*$_n$, *net_max*$_n$, and *net_reserve*$_n$ (see Table 12-54) are set to the same value, then the PTM-TC stream is designated as a fixed data rate PTM-TC stream (i.e., RA-MODE = MANUAL, see Table 12-49). If $net\_min_n = net\_reserve_n$ and $net\_min_n \neq net\_max_n$, then the PTM-TC stream is designated as a flexible data rate PTM-TC stream. If the value of $net\_min_n \neq net\_max_n \neq net\_reserve_n$, then the PTM-TC stream is designated as a flexible data rate PTM-TC stream with reserved data rate allocation.

During initialization and reconfiguration procedures (except SOS), the actual net data rate *net_act*$_n$ for stream #*n* shall always be set to the value of the derived parameter NDR_{pn} of the underlying PMS-TC latency path function and shall be constrained such that $net\_min_n \leq net\_act_n \leq net\_max_n$. However, in case the $net\_min_n = net\_max_n$, the *net_act*$_n$ may exceed the *net_max*$_n$ by up to 8 kbit/s, to allow for the PMS-TC net data rate granularity (see Table 5-1). If $net\_min_n < net\_max_n$, the *net_max*$_n$ shall be set at least 8 kbit/s above the *net_min*$_n$, to allow for the PMS-TC net data rate granularity to meet the $net\_min_n \leq net\_act_n \leq net\_max_n$ requirement. The actual latency *delay_act*$_n$ of transport of stream #*n* shall always be set to the value of the derived parameter $delay_p$ of the underlying PMS-TC latency path function and constrained such that $delay\_act_n \leq delay\_max_n$.

The actual impulse noise protection *INP_act*$_n$ of transport of stream #*n* shall always be set to the value of the derived parameter INP_p of the underlying PMS-TC path function and constrained such that $INP\_act_n \geq INP\_min_n$. The values *net_act*$_n$, *delay_act*$_n$ and *INP_act*$_n$ are not control parameters; these values are the result of specific initialization and reconfiguration procedures.

During SOS reconfiguration procedures, the net data rates, INP and delay shall comply with clause 13.4.

L.3.7.1 Valid configuration

The configurations listed in Table L.16 are valid for the PTM-TC function.

Table L.16 – Valid configuration for PTM-TC function

Parameter	Capability
$type_n$	3
net_min_n	net_min_n may be supported for all valid framing configurations.
net_max_n	net_max_n may be supported for all valid framing configurations.
$net\_reserve_n$	$net\_reserve_n$ may be supported for all valid framing configurations.
$MIN\text{-}SOS\text{-}BR_n$	$MIN\text{-}SOS\text{-}BR_n$ may be supported for all valid framing configurations.
$delay\_max_n$	All valid values of $delay\_max_n$ (see Table 12-51).
INP_min_n	All valid values of INP_min_n (see Table 12-51).
$CIpolicy_n$	0, 1, 2

L.3.7.2 Mandatory configurations

If implementing a PTM-TC function, a VTU shall support all combinations of the values of PTM-TC control parameters for PTM-TC function #0 displayed in Tables L.17 and L.18 in the downstream and upstream directions, respectively. The transmitter and receiver shall support mandatory features displayed in these tables and in Table L.19.

Table L.17 – Mandatory downstream configuration for PTM-TC function #0

Parameter	Capability
$type_n$	3
$delay\_max_n$	All valid values shall be supported.
INP_min_n	All valid values shall be supported.
$CIpolicy_n$	0

Table L.18 – Mandatory upstream configuration for PTM-TC function #0

Parameter	Capability
$type_n$	3
$delay\_max_n$	All valid values shall be supported.
INP_min_n	All valid values shall be supported.

Table L.19 – Mandatory bidirectional configuration for PTM-TC function

Parameter	Capability
bi_net_min	*bi_net_min* shall be supported for all valid framing configurations up to and equal to the MBDC defined in clause 6.2.7 for the applicable profile.
bi_net_max	*bi_net_max* shall be supported for all valid framing configurations up to and equal to the MBDC defined in clause 6.2.7 for the applicable profile.
bi_net_reserve	*bi_net_reserve* shall be supported for all valid framing configurations up to and equal to the MBDC defined in clause 6.2.7 for the applicable profile.

L.3.8 Functionality

The functionality of the PTM-TC shall implement 64/65-octet encapsulation as defined in Annex N of [ITU-T G.992.3], and shall include encapsulation, packet error monitoring, data rate decoupling, and frame delineation.

For frame error monitoring, the transmitting PTM-TC shall insert the 16-bit CRC defined in clause N.3.3 of [ITU-T G.992.3].

L.3.9 Management plane procedures

L.3.9.1 Surveillance primitives

See clause N.4 of [ITU-T G.992.3].

L.3.9.2 Indicator bits

The indicator bits for TPS-TC #*n* and bearer channel #*n* (*n* = 0 or 1) are defined in clause 9.5.2.2. The TIB#*n*-0, TIB#*n*-1, TIB#*n*-2 and TIB#*n*-3 shall be set to a 1 for use in Table 9-5.

L.3.9.3 Overhead command formats

L.3.9.3.1 Inventory command

For further study.

L.3.9.3.2 Control Value Read command

For further study.

L.3.9.3.3 Management Counter Read command

The TPS-TC octets in the response to the overhead Management Counter Read command corresponding to the PTM-TC function are under study. The block of counter values corresponding to the PTM-TC function returned in the message described in Table 11-18 shall have zero length.

L.3.10 Initialization procedure

The PTM-TC shall be configured during initialization using the same procedure described in clause L.1.10.

L.3.11 On-line reconfiguration

The on-line reconfiguration of the PTM-TC is outside the scope of this Recommendation. There is no specified mechanism to modify the value of the control parameters of the PTM-TC function. The values of *net_act* and *delay_act* are automatically updated from the underlying PMS-TC latency path function.

L.3.11.1 Changes to an existing stream

Update of the *net_act* and *delay_act* parameters of an existing PTM-TC function shall only occur at octet boundaries. The transmit PTM-TC function uses the new values of the *net_act*, and *delay_act* to generate octets that follow the signalling of the Frame.Synchflag.confirm primitive. The receive PTM-TC function procedures process octets that follow the signalling of the Frame.Synchflag.indicate primitive using the new values of these parameters.

Annex M

Time-of-day distribution over VDSL2 links

(This annex forms an integral part of this Recommendation.)

This annex defines the procedure for distribution of time-of-day across a VDSL2 link. Each section in this annex identifies the corresponding clause in the main body for which supplements or amendments are made in support of time-of-day distribution over VDSL2 links.

M.1 Time-of-day distribution operational overview

See clause 8.4.1.

M.2 Definitions

See clause 3.

M.3 Abbreviations

See clause 4.

M.4 VTU functional model

See clause 5.1.

M.5 TPS-TC function

See clause 8 (i.e., text between headings of clause 8 and clause 8.1).

M.6 eoc communication protocol

See clause 8.2.4.1.

M.7 ToD TPS-TC (ToD-TC)

See clause 8.4.

M.8 Mapping of OH data

See clause 9.5.2.2.1.

M.9 eoc transmission protocol

See clause 11.2.2 (transmission protocol).

See clause 11.2.3.2 (Command and response types).

M.10 Frequency synchronization command

See clause 11.2.3.14.

M.10.1 The eoc data rate to transport the ToD phase difference values (informative)

This informative clause contains a calculation of the required eoc data rate to transport the ToD phase difference values.

The model of the eoc transmitter is shown in Figure M.1. Two cases are illustrated in Figure M.2.

- Case 1: Transfer of high priority message ongoing when ToD frequency synchronization message is to be sent;

- Case 2: Transfer of lower priority message ongoing when ToD frequency synchronization message is to be sent.

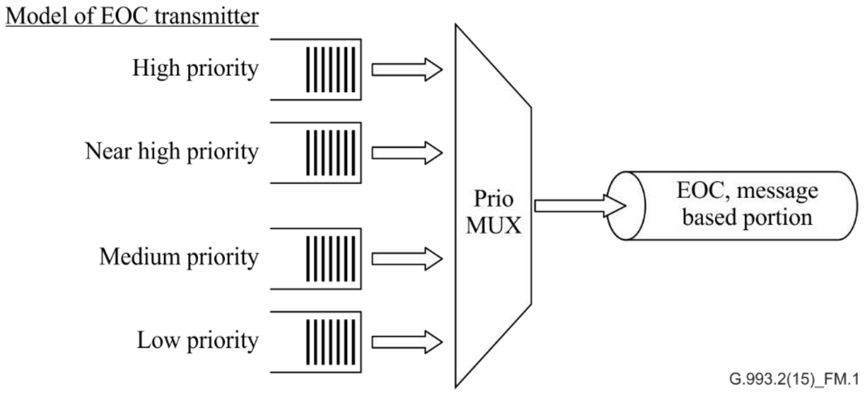

Figure M.1 – Model of the eoc transmitter

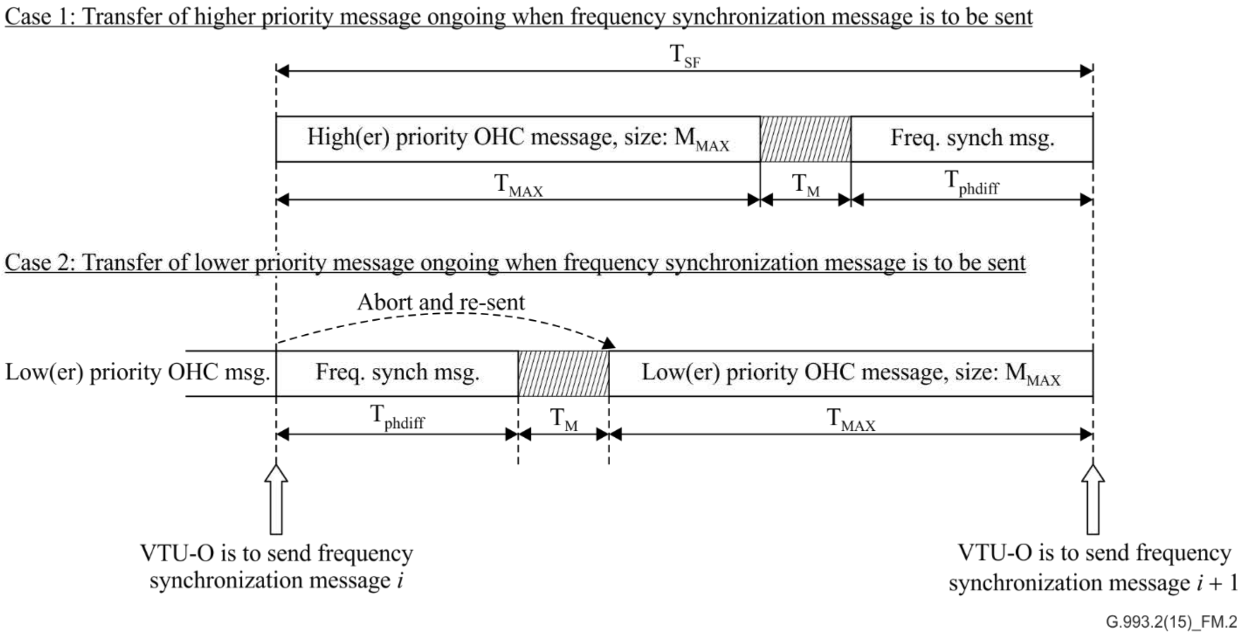

Figure M.2 – Two cases of ongoing transfers

Variables and Calculation:

$\mathrm{msg}_\mathrm{p} msg_p$ [Kbit/s] message overhead data rate (Table 9-8)

M_{max} [Octets] maximum size of any eoc message fragment (1 024 octets, see clause 11.2.3.1)

M_{phdiff} [Octets] size of periodic ToD frequency synchronization message

T_{SF} [s] repetition period of time synchronization messages

f_{DMT} [kHz] DMT symbol rate (clause 10.4.4.)

$T_{SF} = \frac{n \times 257}{f_{DMT}}$ with n being agreed between VTUs during initialization (n = 1, 2 … 255)

T_{max} [s] time required for transmission of message of size M_{max}

T_{phdiff} [s] time required for transmission of message of size M_{phdiff}

$T_m = \alpha \times T_{max}$	α denoting a percentage of T_{max} to be considered as margin T_m. The margin takes care for HDLC framing overhead and software reaction times when scheduling OHC messages.

Condition for deterministic exchange of periodic message along with maximum sized messages:

$$T_{SF} \geq T_{max} + T_{phdiff} + T_m$$

with $msg_p \times T_{max} = M_{max}$ and equivalent for the other contributors, the condition is expressed as

$$msg_p \geq \frac{8}{T_{SF}} \times \left(M_{phdiff} + (1+\alpha) \times M_{\max}\right)$$

considering the operator configured parameter msg_{min} in addition:

$$msg_p \geq \min\left\{\frac{8}{T_{SF}} \times \left(M_{phdiff} + (1+\alpha) \times M_{\max}\right);\ msg_{\min}\right\} \quad (M.1)$$

Using typical values for the aforementioned parameters, the following table can be generated:

n	f_s [kHz]	T_{SF} [s]	M_{phdiff}	M_{max} [Oct]	α	msg_{min} [Kbit/s]	msg_p [Bit/s]	msg_p [Kbit/s]	Percentage of eoc bandwidth for phase difference [%]
1	4	0.06425	5	512	0.1	16	70 749	71	0.9

M.11 Time synchronization command and responses

See clause 11.2.3.15.

M.12 Updates to initialization

See clause 12.3.5.2 (SOC messages exchanged during channel analysis and exchange phase).

See 12.3.5.2.1.1 (O-MSG 1 field #27).

See 12.3.5.2.1.2 (O-TPS field #7).

See 12.3.5.2.2.1 (R-MSG 2 fields #9 and #10).

Annex N

Region D (China)

(This annex forms an integral part of this Recommendation.)

N.1 Band plans

This annex defines the band plan for the Chinese region for VDSL2 systems. The band plans are defined in Table N.1 below and can be summarized as follows:

Plan CN17 Band plan to f_{max} = 17.664 MHz

Plan CN35 Band plan to f_{max} = 35.328 MHz

Different variants are defined for band plans CN17 and CN35 to accommodate different underlying services (POTS and ISDN), and different US0 bandwidths.

NOTE – In the scenario of band plans CN17 and CN35 coexistence, the out-of-band transmit and receive PSDs of CN17 may lead to near-end and far-end crosstalk between lines operating per band plan CN17 and lines operating per band plan CN35.

Table N.1 – Band-edge frequencies for Chinese VDSL2 band plans

Band plan	Band-edge frequencies (as defined in the generic band plan in clause 7.1.2)							
	f_{0L} kHz	f_{0H} kHz	f_1 kHz	f_2 kHz	f_3 kHz	f_4 kHz	f_5 kHz	f_6 kHz
	US0		DS1	US1	DS2	US2	DS3	
CN17	25	138	138	3 750	5 200	14 200	17 664	N/A
	120	276	276					
	25	276	276					
	N/A	N/A	276					
CN35	25	138	138	3 750	5 200	14 200	17 664	35 328
	120	276	276					
	25	276	276					
	N/A	N/A	276					
NOTE 1 – N/A in the columns f_{0L} and f_{0H} designates a band plan variant that does not use US0.								
NOTE 2 – The capability to support US0 together with profile 17a is required for Chinese VDSL2.								

The f_i in Table N.1 are defined as follows:

- f_{0L} and f_{0H}: define lower and upper frequency of US0;
- f_1 to f_3 are the boundary frequencies of the bands DS1 and US1 as defined for CN17;
- f_4 to f_5 are the boundary frequencies of the bands DS2 and US2 for CN17;
- f_5 to f_6 are the boundary frequencies of the band DS3 for CN35.

N.2 Limit PSD mask options

The limit PSD mask options defined in this Annex are shown in Table N.2, for various band plans.

Table N.2 – Chinese limit PSD mask options for band plans CN17 and CN35

Short name	Limit PSD mask (long name)	Frequency	
		US0 type A/B/M (Note)	Highest used upstream or downstream frequency (kHz)
D-1	CN17-M2x-A	A	17 664
D-2	CN17-M2x-B	B	17 664
D-3	CN17-M2x-M	M	17 664
D-4	CN17- M2x-NUS0-M	N/A	17 664
D-5	CN35-M2x-A	A	35 328
D-6	CN35-M2x-B	B	35 328
D-7	CN35-M2x-M	M	35 328
D-8	CN35- M2x-NUS0-M	N/A	35 328

NOTE – The US0 types stand for:

- US0 type A corresponds to Annex A of [ITU-T G.993.2 Annex B];
- US0 type B corresponds to Annex B of [ITU-T G.993.2 Annex B];
- US0 type M corresponds to Annex M of [ITU-T G.993.2 Annex B];
- US0 type N/A designates a band plan variant that does not use US0;
- CN17-M2x-NUS0-M and CN35-M2x-NUS0-M designate the variants in which DS1 starts at 276 kHz instead of 138 kHz.

N.2.1 General requirements in the band below 4 kHz

The noise in the voice band measured with psophometric weighting according to [ITU-T O.41] clause 3.3 shall not exceed –6dBm. The psophometer shall be used in bridging mode and shall be calibrated for 600-ohm termination.

N.2.2 VTU-R limit PSD masks for band plans CN17 and C35

The VTU-R limit PSD masks for band plans CN17 and CN35 are shown in Table N.3.

Table N.3 – VTU-R limit PSD masks for band plans CN17 and CN35

Name	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8
Long name	**CN17-M2x-A**	**CN17-M2x-B**	**CN17-M2x-M**	**CN17- M2x-NUS0-M**	**CN35-M2x-A**	**CN35-M2x-B**	**CN35-M2x-M**	**CN35- M2x-NUS0-M**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
0	–97.5	–97.5	–97.5	–100	–97.5	–97.5	–97.5	–100
4	–97.5	–97.5	–97.5	–100	–97.5	–97.5	–97.5	–100
4	–92.5	–92.5	–92.5	–100	–92.5	–92.5	–92.5	–100
25.875	–34.5	–92.5	–37.5	–100	–34.5	–92.5	–37.5	–100
50	–34.5	–90	–37.5	–100	–34.5	–90	–37.5	–100
80	–34.5	–81.8	–37.5	–100	–34.5	–81.8	–37.5	–100
120	–34.5	–34.5	–37.5	–100	–34.5	–34.5	–37.5	–100
138	–34.5	–34.5	–37.5	–100	–34.5	–34.5	–37.5	–100
225	Interp	–34.5	–37.5	–100	Interp	–34.5	–37.5	–100
243	–93.2	–34.5	–37.5	–100	–93.2	–34.5	–37.5	–100
276	Interp	–34.5	–37.5	–100	Interp	–34.5	–37.5	–100
307	Interp	Interp	Interp	–100	Interp	Interp	Interp	–100
493.41	Interp	Interp	–97.9	–100	Interp	Interp	–97.9	–100
508.8	Interp	–98	Interp	–100	Interp	–98	Interp	–100
686	–100	–100	–100	–100	–100	–100	–100	–100
3 575	–100	–100	–100	–100	–100	–100	–100	–100
3 750	–80	–80	–80	–80	–80	–80	–80	–80
3 750	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2
5 100	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp
5 200	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7
5 200	–80	–80	–80	–80	–80	–80	–80	–80
5 375	–100	–100	–100	–100	–100	–100	–100	–100

Table N.3 – VTU-R limit PSD masks for band plans CN17 and CN35

Name	**D-1**	**D-2**	**D-3**	**D-4**	**D-5**	**D-6**	**D-7**	**D-8**
Long name	**CN17-M2x-A**	**CN17-M2x-B**	**CN17-M2x-M**	**CN17- M2x-NUS0-M**	**CN35-M2x-A**	**CN35-M2x-B**	**CN35-M2x-M**	**CN35- M2x-NUS0-M**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
8 325	–100	–100	–100	–100	–100	–100	–100	–100
8 500	–100	–100	–100	–100	–100	–100	–100	–100
8 500	–100	–100	–100	–100	–100	–100	–100	–100
10 000	–100	–100	–100	–100	–100	–100	–100	–100
12 000	–100	–100	–100	–100	–100	–100	–100	–100
12 000	–100	–100	–100	–100	–100	–100	–100	–100
12 175	–100	–100	–100	–100	–100	–100	–100	–100
14 000	–100	–100	–100	–100	–100	–100	–100	–100
14 000	–100	–100	–100	–100	–100	–100	–100	–100
14 025	–100	–100	–100	–100	–100	–100	–100	–100
14 200	–80	–80	–80	–80	–80	–80	–80	–80
14 200	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
15 700	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
17 664	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
17 664	–56.5	–56.5	–56.5	–56.5	–80	–80	–80	–80
17 839	Interp	Interp	Interp	Interp	–100	–100	–100	–100
21 000	–80	–80	–80	–80	–100	–100	–100	–100
21 450	–100	–100	–100	–100	–100	–100	–100	–100
21 450	–100	–100	–100	–100	–100	–100	–100	–100
24 715	–100	–100	–100	–100	–100	–100	–100	–100
24 890	–100	–100	–100	–100	–100	–100	–100	–100
24 890	–100	–100	–100	–100	–100	–100	–100	–100

Table N.3 – VTU-R limit PSD masks for band plans CN17 and CN35

Name	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8
Long name	**CN17-M2x-A**	**CN17-M2x-B**	**CN17-M2x-M**	**CN17- M2x-NUS0-M**	**CN35-M2x-A**	**CN35-M2x-B**	**CN35-M2x-M**	**CN35- M2x-NUS0-M**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
25 065	–100	–100	–100	–100	–100	–100	–100	–100
30 000	–100	–100	–100	–100	–100	–100	–100	–100
30 000	–110	–110	–110	–110	–110	–110	–110	–110
30 175	–110	–110	–110	–110	–110	–110	–110	–110
35 328	–110	–110	–110	–110	–110	–110	–110	–110
≥ 35 328	–110	–110	–110	–110	–110	–110	–110	–110

NOTE – The PSD values between breakpoints including the values marked by "Interp" shall be obtained by interpolation between adjacent breakpoints as follows:

– below 3575 kHz on a dB/log(*f*) basis; and
– above 3575 kHz on a dB/*f* basis.

N.2.3 VTU-O limit PSD masks for band plans CN17 and CN35

The VTU-O limit PSD masks for band plan CN17 and CN35 are shown in Table N.4.

Table N.4 – VTU-O limit PSD masks for band plans CN17 and CN35

Name	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8
Long name	**CN17-M2x-A**	**CN17-M2x-B**	**CN17-M2x-M**	**CN17- M2x-NUS0-M**	**CN35-M2x-A**	**CN35-M2x-B**	**CN35-M2x-M**	**CN35- M2x-NUS0-M**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
0	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5
4	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5	–97.5
4	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5	–92.5
80	–72.5	–92.5	–92.5	–92.5	–72.5	–92.5	–92.5	–92.5
101.2	Interp	–92.5	–92.5	–92.5	Interp	–92.5	–92.5	–92.5

Table N.4 – VTU-O limit PSD masks for band plans CN17 and CN35

Name	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8
Long name	**CN17-M2x-A**	**CN17-M2x-B**	**CN17-M2x-M**	**CN17- M2x-NUS0-M**	**CN35-M2x-A**	**CN35-M2x-B**	**CN35-M2x-M**	**CN35- M2x-NUS0-M**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
138	–44.2	Interp	Interp	Interp	–44.2	Interp	Interp	Interp
138	–36.5	Interp	Interp	Interp	–36.5	Interp	Interp	Interp
227.11	–36.5	–62	–62	–62	–36.5	–62	–62	–62
276	–36.5	–48.5	–48.5	–48.5	–36.5	–48.5	–48.5	–48.5
276	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5
1 104	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5	–36.5
1 622	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5	–46.5
2 208	–48	–48	–48	–48	–48	–48	–48	–48
2 249	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp
2 500	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp
3 750	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2	–51.2
3 750	–80	–80	–80	–80	–80	–80	–80	–80
3 925	–100	–100	–100	–100	–100	–100	–100	–100
5 025	–100	–100	–100	–100	–100	–100	–100	–100
5 200	–80	–80	–80	–80	–80	–80	–80	–80
5 200	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7	–52.7
7 050	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp
7 225	Interp	Interp	Interp	Interp	Interp	Interp	Interp	Interp
8 500	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8	–54.8
10 000	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5
12 000	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5	–55.5
12 000	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5

Table N.4 – VTU-O limit PSD masks for band plans CN17 and CN35

Name	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8
Long name	**CN17-M2x-A**	**CN17-M2x-B**	**CN17-M2x-M**	**CN17- M2x-NUS0-M**	**CN35-M2x-A**	**CN35-M2x-B**	**CN35-M2x-M**	**CN35- M2x-NUS0-M**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
13 825	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
14 000	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
14 200	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5	–56.5
14 200	–80	–80	–80	–80	–80	–80	–80	–80
14 375	–100	–100	–100	–100	–100	–100	–100	–100
17 489	–100	–100	–100	–100	–100	–100	–100	–100
17 664	–100	–100	–100	–100	–80	–80	-80	–80
17 664	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5
21 000	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5
21 450	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5
21 450	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5
21 625	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5
24 715	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5
24 890	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5
24 890	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5
25 065	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5
30 000	–100	–100	–100	–100	–56.5	–56.5	–56.5	–56.5
30 000	–110	–110	–110	–110	–73	–73	–73	–73
30 175	–110	–110	–110	–110	Interp	Interp	Interp	Interp
35 328	–110	–110	–110	–110	–73.4	–73.4	–73.4	–73.4
37 000	–110	–110	–110	–110	–83	–83	–83	-83
40 656	–110	–110	–110	–110	–110	–110	–110	–110

Table N.4 – VTU-O limit PSD masks for band plans CN17 and CN35

Name	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8
Long name	**CN17-M2x-A**	**CN17-M2x-B**	**CN17-M2x-M**	**CN17- M2x-NUS0-M**	**CN35-M2x-A**	**CN35-M2x-B**	**CN35-M2x-M**	**CN35- M2x-NUS0-M**
kHz	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**	**dBm/Hz**
> 40 656	–110	–110	–110	–110	-110	–110	–110	–110

NOTE – The PSD values between breakpoints including the values marked by "Interp" shall be obtained by interpolation between adjacent breakpoints as follows:

– below f_1 on a dB/log(f) basis; and

– above f_1 on a dB/f basis,

where f_1 is defined in Table N.1 as either 138 or 276 kHz.

N.3 UPBO reference PSDs

UPBO parameters '*a*' and '*b*' are set by network management.

NOTE – The parameters '*a*' and '*b*' are expected to be uniform across all lines sharing a section of cable plant.

N.4 Template PSD

N.4.1 Definition

The template PSD is set to 3.5 dB below the PSD mask in frequency bands in which the PSD is at or above −96.5 dBm/Hz. Elsewhere the template is set to −100 dBm/Hz below 4 MHz, −110 dBm/Hz between 4 MHz and f_3, or −112 dBm/Hz between f_3 and 35.328 MHz, where f_3 is defined in Table N.1. These values are chosen to satisfy the requirements of clause 7.2.2 in ITU-T G.993.2.

N.4.2 Narrow-band PSD verification

Narrow-band compliance with the PSD masks in this annex shall be verified by power measurements using a 10-kHz measurement bandwidth centred on the frequency in question above 4 kHz, and in a 100-Hz measurement bandwidth in the band up to 4 kHz.

N.4.3 Use in simulation (informative)

The Template PSD may be used in simulations of VDSL2 performance as representative of an average transmitter conformant with the associated limit PSD mask.

N.5 Compliance

Compliance requires conformance with at least one limit PSD mask.

Annex O

This annex is intentionally left blank.

Annex P

Short reach VDSL2 with reduced power and enhanced data rate

(This annex forms an integral part of this Recommendation.)

P.1 Scope

This annex defines the functional requirements for implementations of ITU-T G.993.2 with reduced power and enhanced data rates over a short reach (e.g., for deployment from the distribution point (DP)). The defined functionalities concern the transmit power, support of enhanced net data rates in [ITU-T G.998.4], SRA and TPS-TC. Other functionalities are for further study.

P.2 Reduced ATP

A VTU-O compliant with this annex may indicate in the ITU-T G.993.2 discovery phase a MAXNOMATPds parameter value that is lower than the maximum aggregate downstream transmit power in the VDSL2 profile (see Tables 12-21 and 6-1), and lower than the MAXNOMATPds value configured in the CO-MIB (see clause 7.3.1.2.3 of [ITU-T G.997.1]).

NOTE – The VTU-O MAXNOMATPds parameter value may be lowered due to a specific deployment scenario.

P.3 Minimum bidirectional net data rate capability

A VTU compliant with this annex shall comply with the following minimum bidirectional net data rate capability for the profiles listed in Table P.1. These values supersede the values specified in Table 6-1.

Table P.1 – Annex P profiles

Frequency plan	Parameter	Parameter value for profile	
		17a	**30a**
All	Minimum bidirectional net data rate capability (MBDC)	150 Mbit/s	250 Mbit/s

NOTE – For the profile 30a in operation according to Annex B, it is recommended that the Limit Mask PSD B8-16 (long name 998ADE30-M2x-NUS0-A) is configured in the CO-MIB.

Support of profile 30a is mandatory for compliance with this annex. Support of profile 17a is optional.

P.4 ITU-T G.998.4 Annex D support for enhanced net data rates with ITU-T G.998.4

Support for ITU-T G.998.4 downstream retransmission is mandatory for a VTU compliant with this annex.

Support for ITU-T G.998.4 upstream retransmission is optional for a VTU compliant with this annex.

A VTU compliant with this annex shall support Annex D of ITU-T G.998.4 without requiring bit "ITU-T G.993.5" (see Table 11.68.0.1 of ITU-T G.994.1) to be set to ONE in the Spar(2) octet 2 of ITU-T G.993.2 at the VTU-O.

A VTU-O compliant with this annex shall set the bit "ITU-T G.998.4 Annex D support" (see Table 11.68.11 of [ITU-T G.994.1]) to ONE in the "ITU-T G.998.4 extensions" NPar(3) field of the CL message.

A VTU-R compliant with this annex shall set the bit " ITU-T G.998.4 Annex D support" (see Table 11.68.11 of [ITU-T G.994.1]) to ONE in the "ITU-T G.998.4 extensions" NPar(3) field of the CLR message.

A VTU-O compliant with this annex shall support an AggAchievableNDR_O equal to the MaxAggAchievableNDR as defined in Annex D of [ITU-T G.998.4] for the respective VDSL2 profile.

If a VTU-R compliant with this annex supports ITU-T G.998.4 upstream retransmission, it shall support an AggAchievableNDR_R equal to the MaxAggAchievableNDR, as defined in Annex D of [ITU-T G.998.4] for the respective VDSL2 profile.

P.5 SRA support

A VTU-O compliant with this annex shall support OLR type 3:

- in downstream (i.e., bit s=1 in the field "Downstream OLR capabilities" (see Table 12-52) of the "PMS-TC capabilities of the VTU-O" field in O-MSG1); and
- in upstream (i.e., bit s=1 in the field "Upstream OLR capabilities" (see Table 12-52) of the "PMS-TC capabilities of the VTU-O" field in O-MSG1).

A VTU-O compliant with this annex shall support OLR type 5:

- in downstream (i.e., bit s=1 in field #7 "Downstream OLR capabilities with ITU-T G.998.4" (see Table C.4 of [ITU-T G.998.4]) of the "ITU-T G.998.4 parameter field for O-PMS"); and
- in upstream (i.e., bit s=1 in field #8 "Upstream OLR capabilities with ITU-T G.998.4" (see Table C.4 of [ITU-T G.998.4]) of the "ITU-T G.998.4 parameter field for O-PMS").

A VTU-R compliant with this annex shall support OLR type 3:

- in downstream (i.e., bit s=1 in the field "Downstream OLR capabilities" (see Table 12-62) of the "PMS-TC capabilities of VTU-R" field in R-MSG2); and
- in upstream (i.e., bit s=1 in the field "Upstream OLR capabilities" (see Table 12-62) of the "PMS-TC capabilities of VTU-R" field in R-MSG2).

A VTU-R compliant with this annex shall support OLR type 5 in downstream (i.e., bit s=1 in field #7 "Downstream OLR capabilities with ITU-T G.998.4" (see Table C.6 of [ITU-T G.998.4]) of the "ITU-T G.998.4 parameter field for R-PMS").

If a VTU-R compliant with this annex supports ITU-T G.998.4 upstream retransmission, it shall support OLR type 5 in upstream (i.e., bit s=1 in field #8 "Upstream OLR capabilities with ITU-T G.998.4" (see Table C.6 of [ITU-T G.998.4]) of the "ITU-T G.998.4 parameter field for R-PMS").

P.6 TPS-TC

Support of PTM-TC is mandatory for a VTU compliant with this annex.

Annex Q

Enhanced data rate 35 MHz VDSL2 with 4.3125 kHz subcarrier spacing

(This annex forms an integral part of this Recommendation.)

Q.1 Scope

This annex defines functional requirements for implementations of ITU-T G.993.2 operating on frequencies up to 35.324 MHz with subcarrier spacing of 4.3125 kHz, supporting vectoring that is compatible with ITU-T G.993.2 profile 17a. The defined functionalities concern capabilities related to the profile, support of enhanced net data rates in ITU-T G.998.4, SRA and TPS-TC. Other functionalities are for further study.

Q.2 Capabilities related to the profile

A VTU compliant with this annex shall comply with the following capabilities related to the profiles listed in Table Q.1. The profile 17a values supersede the values specified in Table 6-1. The profile 35b values shall be equal to the profile 30a values listed in Table 6-1, with differences specified in Table Q.1.

Table Q.1 – Annex Q profiles

Frequency plan	Parameter	Parameter value for profile	
		17a	35b (Note)
All	Maximum aggregate downstream transmit power (dBm)	*(no change)*	+17
All	Subcarrier spacing (kHz)	*(no change)*	4.3125
All	Support of upstream band zero (US0)	*(no change)*	Regional annex dependent
All	Minimum bidirectional net data rate capability (MBDC)	150 Mbit/s	400 Mbit/s
All	Parameter (1/S)max downstream	*(no change)*	48
All	Parameter (1/S)max upstream	*(no change)*	24
Annex A (998-35b)	Index of highest supported downstream data-bearing subcarrier (upper band edge frequency in MHz (informative))	*(no change)*	8191 (35.324)
	Index of highest supported upstream data-bearing subcarrier (upper band edge frequency in MHz (informative))	*(no change)*	2782 (12.0)
Annex B (998ADE)	Index of highest supported downstream data-bearing subcarrier (upper band edge frequency in MHz (informative))	*(no change)*	8191 (35.324)
	Index of highest supported upstream data-bearing subcarrier (upper band edge frequency in MHz (informative))	*(no change)*	2782 (12.0)
Annex B (998E)	Index of highest supported downstream data-bearing subcarrier (upper band edge frequency in MHz (informative))	*(no change)*	8191 (35.324)
	Index of highest supported upstream data-bearing subcarrier (upper band edge frequency in MHz (informative))	*(no change)*	3246 (14.0)

Table Q.1 – Annex Q profiles

Frequency plan	Parameter	Parameter value for profile	
		17a	35b (Note)
Annex N (CN35)	Index of highest supported downstream data-bearing subcarrier (upper band edge frequency in MHz (informative))	*(no change)*	8191 (35.324)
	Index of highest supported upstream data-bearing subcarrier (upper band edge frequency in MHz (informative))	*(no change)*	4 095 (17.660)
NOTE – Band plans associated with this profile shall have an index of highest supported upstream data-bearing subcarrier not higher than 4095.			

Support of profile 35b is mandatory for compliance with this annex. Support of profile 17a is optional.

Q.3 ITU-T G.998.4 Annex D support for enhanced net data rates

Support for ITU-T G.998.4 downstream retransmission is mandatory for a VTU compliant with this annex.

NOTE 1 – Setting RTX_MODEds = 0 (RTX_FORBIDDEN: ITU-T G.998.4 retransmission not allowed) may result in reduced bit rates and impulse noise protection, and thus is not recommended.

Support for ITU-T G.998.4 upstream retransmission is optional for a VTU compliant with this annex.

A VTU compliant with this annex shall support Annex D of [ITU-T G.998.4] without requiring bit "ITU-T G.993.5" (see Table 11.68.0.1 of [ITU-T G.994.1]) to be set to ONE in the Spar(2) octet 2 of ITU-T G.993.2 at the VTU-O.

A VTU-O compliant with this annex shall set the bit "ITU-T G.998.4 Annex D support" (see Table 11.68.11 of [ITU-T G.994.1]) to ONE in the "ITU-T G.998.4 extensions" NPar(3) field of the CL message.

A VTU-R compliant with this annex shall set the bit "ITU-T G.998.4 Annex D support2 (see Table 11.68.11 of [ITU-T G.994.1]) to ONE in the 2ITU-T G.998.4 extensions2 NPar(3) field of the CLR message.

The reference half roundtrip (HRT_{ref}) values for determining AggAchievableNDR_O are the following:

- Profile 17a: HRT_{ref} = 8 DMT symbols;
- Profile 35b: HRT_{ref} = 6 DMT symbols.

The reference half roundtrip (HRT_{ref}) values for determining AggAchievableNDR_R are the following:

- Profile 17a: HRT_{ref} = 8 DMT symbols;
- Profile 35b: HRT_{ref} = 7 DMT symbols.

NOTE 2 – With nominal values of CE, the HRTref of 8 symbols, 7 symbols, and 6 symbols are equal to 2 ms, 1.75 ms and 1.5 ms, respectively.

The maximum aggregate achievable net data rate (MaxAggAchievableNDR, see clause D.1.1.1 of [ITU-T G.998.4]) for each profile, are the following:

- Profile 17a = 150 Mbit/s;
- Profile 35b = 400 Mbit/s.

A VTU-O compliant with this annex with support for ITU-T G.998.4 upstream retransmission, shall support an AggAchievableNDR_O (see clause D.1.1.1 of [ITU-T G.998.4]) equal to the MaxAggAchievableNDR for the profile17a and equal to 355 Mbit/s for the profile 35b.

A VTU-R compliant with this annex with support of ITU-T G.998.4 upstream retransmission, shall support an AggAchievableNDR_R (see clause D.1.1.1 of [ITU-T G.998.4]) equal to the MaxAggAchievableNDR for the profile 17a and equal to 355 Mbit/s for the profile 35b.

For profile 35b, the valid values for (derived) framing parameters shall be as listed in Table 9-9, Table 9-3 of [ITU-T G.998.4] and Table C.1 of [ITU-T G.998.4] for profile 30a, with differences shown in Table Q.2.

Table Q.2 – Valid values for profile 35b

Parameter	downstream	upstream
DTU size after FEC in symbols $(Q \times S_1)$ (see Table 9.3 of [ITU-T G.998.4])	$1/3 \leq Q \times S_1 \leq 4$	*(no change)*
DTU size ($Q \times H$) (see Table C.1 of [ITU-T G.998.4])	≤ 4096	*(no change)*
FEC codewords per symbol ($1/S$) (see Table 9-9)	≤ 48	≤ 24

Q.4 SRA support

A VTU-O compliant with this annex shall support OLR Type 3:

- in downstream (i.e., bit s=1 in the Field "Downstream OLR capabilities" (see Table 12-52) of the "PMS-TC capabilities of the VTU-O" field in O-MSG1); and
- in upstream (i.e., bit s=1 in the Field "Upstream OLR capabilities" (see Table 12-52) of the "PMS-TC capabilities of the VTU-O" field in O-MSG1).

A VTU-O compliant with this annex shall support OLR Type 5:

- in downstream (i.e., bit s=1 in Field #7 "Downstream OLR capabilities with ITU-T G.998.4" (see Table C.4 of [ITU-T G.998.4]) of the "G.998.4 parameter field for O-PMS"); and
- in upstream (i.e., bit s=1 in Field #8 "Upstream OLR capabilities with ITU-T G.998.4" (see Table C.4 of [ITU-T G.998.4]) of the "G.998.4 parameter field for O-PMS").

A VTU-R compliant with this annex shall support OLR Type 3:

- in downstream (i.e., bit s=1 in the Field "Downstream OLR capabilities" (see Table 12-62) of the "PMS-TC capabilities of VTU-R" field in R-MSG2); and
- in upstream (i.e., bit s=1 in the Field "Upstream OLR capabilities" (see Table 12-62) of the "PMS-TC capabilities of VTU-R" field in R-MSG2).

A VTU-R compliant with this annex shall support OLR Type 5 in downstream (i.e., bit s=1 in Field #7 "Downstream OLR capabilities with ITU-T G.998.4" (see Table C.6 of [ITU-T G.998.4]) of the "G.998.4 parameter field for R-PMS").

If a VTU-R compliant with this annex supports G.998.4 upstream retransmission, it shall support OLR Type 5 in upstream (i.e., bit s=1 in Field #8 "Upstream OLR capabilities with ITU-T G.998.4" (see Table C.6 of [ITU-T G.998.4]) of the "ITU-T G.998.4 parameter field for R-PMS").

Q.5 TPS-TC

Support of PTM-TC is mandatory for a VTU compliant with this annex.

Q.6 Additional changes to ITU-T G.993.2 for operation according to profile 35b

NOTE – This clause uses revision marks where changes are made relative to the approved text. Unchanged text is replaced by ellipsis (…).

The U reference point specification for operation according to profile 35b shall be the same as specified in the main body of this Recommendation, with differences listed in this clause.

9.5.4 Framing parameters

• • •

Table 9-8 – Framing parameters for latency path *p*

Parameter	Definition
$PERB_p$	The number of bytes in the overhead frame: $$PERB_p = \frac{T_p \times N_{FECp}}{M_p} \times \left\lfloor \frac{\hat{Q} \times M_p}{T_p \times N_{FECp}} \right\rfloor \text{ bytes}$$ where: $$\hat{Q} = \begin{cases} Q & \text{if } TDR_p \geq TDR_0 \\ Q \cdot \frac{TDR_p}{TDR_0} & \text{if } TDR_p < TDR_0 \end{cases}$$ and where: TDR_p is the total data rate of latency path *p* in kbit/s, Q = 17 000 bytes for upstream and 34 000 bytes for downstream, TDR_0 = 7 880 kbit/s for upstream and 15 760 kbit/s for downstream.

• • •

10.4.1 Data subcarriers

• • •

Transmission will take place on *NSC* subcarriers, with $NSC_{us} \leq MSI_{us}$ and $NSC_{ds} \leq MSI_{ds}$; the subcarrier with index i=0 shall not be used. $NSC_{us} + NSC_{ds}$ shall always be less than 8192.

• • •

10.4.3 Modulation by the inverse discrete Fourier transform

• • •

The valid values of N are $N = 2^{n+5}$, where n can take integer values from 0 to 8. The values of N used for upstream and downstream are exchanged during initialization (see clauses 12.3.2, 12.3.3.2.1.3, and 12.3.3.2.2.3).

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11.2.3.3 On-line reconfiguration (OLR) commands and responses

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Table 11-6 – OLR commands sent by the initiating VTU

<table>
<tr><th>Name</th><th>Length (octets)</th><th>Octet number</th><th colspan="2">Content</th><th>Support</th></tr>
<tr><td rowspan="9">Request Type 3 (SRA) (Note 6)</td><td rowspan="9">$5 + 7\ N_{LP} + 4\ N_f$ ($N_f \leq 128$)</td><td>2</td><td colspan="2">06_{16} (Note 1)</td><td rowspan="9">Mandatory</td></tr>
<tr><td>3 to $2 + 3\ N_{LP}$</td><td colspan="2">$3 \times N_{LP}$ octets containing the new L_p values for each of the active latency paths (N_{LP} = number of active latency paths) (Notes 2 and 3)</td></tr>
<tr><td>$3 + 3\ N_{LP}$ to $2 + 5\ N_{LP}$</td><td colspan="2">$2 \times N_{LP}$ octets containing the new D_p values for each of the active latency paths (N_{LP} = number of active latency paths) (Note 4)</td></tr>
<tr><td>$3 + 5\ N_{LP}$ to $2 + 6\ N_{LP}$</td><td colspan="2">N_{LP} octets containing the new T_p values for each of the active latency paths (N_{LP} = number of active latency paths) (Notes 2, 3, 5)</td></tr>
<tr><td>$3 + 6\ N_{LP}$ to $2 + 7\ N_{LP}$</td><td colspan="2">N_{LP} octets containing the new G_p values for each of the active latency paths (N_{LP} = number of active latency paths) (Notes 2, 3, 5)</td></tr>
<tr><td>$3 + 7\ N_{LP}$ to $2 + 8\ N_{LP}$</td><td colspan="2">N_{LP} octets containing the new B_{p0} values for each of the active latency paths (N_{LP} = number of active latency paths) (Notes 2, 3, 5)</td></tr>
<tr><td>$3 + 8\ N_{LP}$ to $4 + 8\ N_{LP}$</td><td colspan="2">2 octets for the number of subcarriers N_f to be modified</td></tr>
<tr><td>$5 + 8\ N_{LP}$ to $4 + 8\ N_{LP} + 4\ N_f$</td><td colspan="2">$4\ N_f$ octets describing the subcarrier parameter field for each subcarrier</td></tr>
<tr><td>$5 + 8\ N_{LP} + 4\ N_f$</td><td colspan="2">1 octet for SC</td></tr>
<tr><td rowspan="9">Request Type 4 (SOS)</td><td rowspan="9">$N_{TG}/2+11$</td><td>2</td><td colspan="2">07_{16} (Note 1)</td><td rowspan="9">Optional</td></tr>
<tr><td>3</td><td colspan="2">Message ID</td></tr>
<tr><td rowspan="4">4 to $N_{TG}/2+3$</td><td>$\Delta b(2)$</td><td>$\Delta b(1)$</td></tr>
<tr><td>$\Delta b(4)$</td><td>$\Delta b(3)$</td></tr>
<tr><td colspan="2">…</td></tr>
<tr><td>$\Delta b(N_{TG})$</td><td>$\Delta b(N_{TG} - 1)$</td></tr>
<tr><td>$N_{TG}/2+4$ to $N_{TG}/2+6$</td><td colspan="2">New value for L_0</td></tr>
<tr><td>$N_{TG}/2+7$ to $N_{TG}/2+9$</td><td colspan="2">New value for L_1</td></tr>
<tr><td>$N_{TG}/2+10$ to</td><td colspan="2">New value for D_0</td></tr>
</table>

Table 11-6 – OLR commands sent by the initiating VTU

Name	Length (octets)	Octet number	Content	Support
		N_{TG}/2+11		
		N_{TG}/2+12 to N_{TG}/2+13	New value for D_1	

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11.2.3.3 On-line reconfiguration (OLR) commands and responses

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Each subcarrier parameter field shall contain 4 octets formatted as [000i iiii iiii iiii gggg gggg gggg bbbb] to convey the g_i (12 bits) and the b_i (4 bits) values of the subcarrier index i (13 bits). The subcarrier index i shall be coded in the five LSBs of the first octet and the entire second octet of the subcarrier field. The LSBs of the subcarrier index i shall be contained in the second octet. The g_i shall be contained in the third octet and the four MSBs of the fourth octet. The LSBs of g_i shall be contained in the fourth octet. The b_i shall be contained in the four LSBs of the fourth octet.

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11.4.1 Test parameters

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Valid values of G are 1, 2, 4 and 8 for upstream and 1, 2, 4, 8 and 16 for downstream.

12.2.1 Message format

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Size in octets	Meaning	Value
1	Flag	$7E_{16}$
1	Address field	Message index
1	Control field	Segmentation index
Up to 2048	Information payload	Payload bytes
1	Frame check sequence	FCS
1	Frame check sequence	FCS
1	Flag	$7E_{16}$

Figure 12-4 – Structure of HDLC frames used in the SOC protocol

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The segmentation index facilitates the message segmentation as described in clause 12.2.6. If no segmentation is used, the segmentation index shall be set to 11_{16}. The number of SOC bytes (before byte stuffing) transmitted in a single HDLC frame shall not exceed 2048.

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12.2.2.1 Automatic repeat (AR) mode

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Table 12-5 – HDLC frames in AR mode

Field	Content
Flag	$7E_{16}$
Message index	01_{16}
Segmentation index	11_{16} if not segmented; as in clause 12.2.6 if segmented
Information payload	Variable, up to 2048 bytes
FCS	Variable
FCS	Variable
Flag	$7E_{16}$

. . .

12.2.6 Segmentation of messages

Messages that are larger than the maximum allowed size (2048 bytes) shall be segmented before transmission; messages shorter than 2048 bytes may also be segmented to improve robustness. To allow segmentation, a segmentation index is included in the control field of the HDLC frame. The four MSBs of this field shall indicate the number of segments, to a maximum of 15, into which the message has been segmented. The four LSBs of this field shall indicate the index of the current segment, starting from 1_{16}. For example, a segmentation index value of 93_{16} indicates the third segment of a total of nine. In case the message is not segmented, the value of the field shall be 11_{16}.

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12.3.2.1.1 CL messages

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Table 12-9 – VTU-O CL message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
Profiles	Each valid profile is represented by one bit in a field of 9 bits. The valid profiles are: 8a, 8b, 8c, 8d, 12a, 12b, 17a, 30a and 35b. Each profile supported by the VTU-O is indicated by setting its corresponding bit to ONE.
Initial IDFT Size (2*N*)	This NPar(3) indicates the initial downstream IDFT size that the VTU-O shall use at the beginning of the channel discovery phase. Bit 5 indicates the use of the extended IDFT size with profile 35b. If set to ONE, it indicates that the IDFT size to be used with profiles 35b is 2N=2×8192. If set to ZERO, it indicates the profile 35b is not supported. The 4 LSBs indicate the IDFT size to be used with any profile other than 35b, encoded as a number from 7 to 13 representing n, where IDFT Size $2N = 2^n$. If no profile other than 35b is supported, the 4 LSBs shall be set to ZERO.

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12.3.2.1.2 MS messages

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Table 12-12 – VTU-O MS message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
Profiles	Each valid profile is represented by one bit in a field of 9 bits. The valid profiles are: 8a, 8b, 8c, 8d, 12a, 12b, 17a, 30a and 35b. The profile selected by the VTU-O is indicated by setting its corresponding bit to ONE.

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12.3.2.2.1 CLR messages

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Table 12-15 – VTU-R CLR message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
Profiles	Each valid profile is represented by one bit in a field of 9 bits. The valid profiles are: 8a, 8b, 8c, 8d, 12a, 12b, 17a, 30a and 35b. Each profile supported by the VTU-R is indicated by setting its corresponding bit to ONE.
Initial IDFT Size (2*N*)	This NPar(3) indicates the initial upstream IDFT size that the VTU-R shall use at the beginning of the channel discovery phase. The bit 5 indicates whether the extended IDFT size shall be used with the profile 35b (ONE) or not (ZERO). If set to ONE, the IDFT size to be used with profiles 35b is 2N=2×8192. If set to ZERO, the IDFT size to be used with profiles 35b is 2N=2×4096. The 4 LSBs indicate the IDFT size to be used with any profile other than 35b, encoded as a number from 6 to 13 representing *n*, where IDFTsize $2N = 2^n$. If no profile other than 35b is supported, the 4 LSBs shall be set to ZERO.

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12.3.2.2.2 MS messages

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Table 12-18 – VTU-R MS message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
Profiles	Each valid profile is represented by one bit in a field of 9 bits. The valid profiles are: 8a, 8b, 8c, 8d, 12a, 12b, 17a, 30a and 35b. The profile selected by the VTU-R is indicated by setting its corresponding bit to ONE.

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12.3.3.2.1.1 O-SIGNATURE

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Fields #2 and #3 shall be formatted as "bands descriptors". The format of the bands descriptor shall be as shown in Table 12-22.

Table 12-22 – Bands descriptor

Octet	Content of field
1	Number of bands to be described
2-5	Bits 0-15: Index of the first subcarrier in band 1 Bits 16-31: Index of the last subcarrier in band 1
6-9 (if applicable)	Bits 0-15: Index of the first subcarrier in band 2 Bits 16-31: Index of the last subcarrier in band 2
etc.	etc.

The first octet of the bands descriptor shall contain the number of bands to be described. This number can be zero. In that case, there shall be no further octets in the descriptor. If the number of bands is not equal to zero, each group of four consecutive octets in the descriptor shall describe the first and last subcarrier in a band.

The first 16 bits (0-15) in the group of four octets shall contain the index of the subcarrier at the lower edge of the band. The last 16 bits (16-31) shall contain the index of the subcarrier at the upper edge of the band. The first and last subcarriers shall be included in the band. For example, a field value $18000E00_{16}$ means that all subcarriers from $0E00_{16}$ = 3 584 to 1800_{16} = 6 144, including subcarriers 3 584 and 6 144, are included in the set.

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Table 12-23 – PSD descriptor

Octet	Content of field
1	Number of subcarriers (or breakpoints) being described
2-5	Bits 0-15: Index of first subcarrier being described Bits 16-31: PSD level in steps of 0.1 dB with an offset of −140 dBm/Hz
6-9 (if applicable)	Bits 0-15: Index of second subcarrier being described Bits 16-31: PSD level in steps of 0.1 dB with an offset of −140 dBm/Hz
etc.	etc.

The first octet of the descriptor shall contain the number of breakpoints being specified. This number can be zero. In that case, there shall be no additional octets in the descriptor. If the number of breakpoints is not equal to zero, each group of four consecutive octets shall describe one breakpoint as a PSD value at a certain subcarrier index.

The first 16 bits (0-15) in the group of three octets shall contain the index of the subcarrier. The last 16 bits (16-31) shall contain the PSD level. The PSD level shall be an integer multiple of 0.1 dB with an offset of −140 dBm/Hz. For example a field value of 03201800_{16} means a PSD of $320_{16} \times 0.1 - 140 = -60$ dBm/Hz on subcarrier index 1800_{16} = 6 144. The PSD level of intermediate unspecified subcarriers shall be obtained using a linear interpolation between the given PSD points (in dBm/Hz) with the frequency axis expressed in a linear scale. The subcarrier indices of the specified breakpoints may be either determined by the CO-MIB or vendor discretionary.

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Field #13 "Downstream transmit window length (β_{ds})" shall contain the length of the downstream transmit window, (β_{ds}), expressed in multiples of 2 samples at the downstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be coded as an 8-bit integer.

NOTE – The phrase "expressed in multiples of 2" means that the actual value used in the transceiver is 2 times the value represented in the field.

Field #14 "Downstream cyclic prefix" shall contain the length of the downstream cyclic prefix expressed in multiples of 2 samples at the downstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be coded as a 16-bit integer.

Field #15 "Initial value of timing advance" indicates the initial timing advance, and shall be expressed either in multiples of 2 samples if profile 35b is used with extended IDFT Size, or otherwise, in samples at the upstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be encoded in a 16-bit field using twos complement format. The special value of $7FFF_{16}$ indicates that the VTU-R shall select the initial setting of the timing advance.

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12.3.3.2.1.2 O-UPDATE

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Field #4 "Highest allowed upstream subcarrier" contains the index of the highest frequency upstream subcarrier that is allowed to be used by the VTU-R. The format shall be a 16-bit value. The subcarrier index shall be described as 13 bits. The three MSBs of the field shall be set to ZERO. The VTU-R shall not allocate power to subcarriers above the highest allowed upstream subcarrier.

Field #5 "Lowest allowed upstream subcarrier" contains the index of the lowest-frequency upstream subcarrier that is allowed to be used by the VTU-R. The format shall be a 16-bit value. The subcarrier index shall be described as 13 bits. The three MSBs of the field shall be set to ZERO. The VTU-R shall not allocate power to subcarriers below the lowest allowed upstream subcarrier.

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Field #7 "Timing advance correction" contains the timing advance correction with respect to the currently used timing advance expressed either in multiples of 2 samples if profile 35b is used with extended IDFT Size, or otherwise, in samples at the upstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be encoded in a 16-bit field using twos complement format. Positive values shall indicate that the transmitted symbol will be advanced more with respect to the received symbol.

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12.3.3.2.1.3 O-PRM

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Field #5 "Downstream cyclic prefix length" contains the value of L_{CP} that shall be applied in the downstream direction starting from the beginning of the training phase. The value shall be expressed in multiples of 2 samples of the downstream sampling rate corresponding to the IDFT size communicated in Field #7. The format shall be the same as for Field #14 of the O-SIGNATURE message (Table 12-21).

Field #6 "Downstream transmit window length (β_{ds})" contains the length of the transmit window that shall be used in the downstream direction starting from the beginning of the training phase. The value shall be expressed in multiples of 2 samples of the downstream sampling rate corresponding to the IDFT size communicated in Field #7. The format shall be the same as for Field #13 of the O-SIGNATURE message (Table 12-21).

Field #7 "VTU-O IDFT size" indicates the updated size of the IDFT at the VTU-O that shall be used in the downstream direction starting from the beginning of the training phase. This value may be different from the initial value that was exchanged during the ITU-T G.994.1 handshake phase. The value shall be expressed as the IDFT size $2N_{ds}$. The format shall be an 8-bit field coded as $\log_2(2N_{ds})$ with valid values from 7 to 14.

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Table 12-31 – Log_tss$_i$ descriptor

Octet	Content of field
1	Number of breakpoints (subcarriers) to be described
2-5	Bits 0-15: Subcarrier index of the first breakpoint Bits 16-31: *log_tss$_i$* value of the first breakpoint in steps of 0.1 dB
6-9 (if applicable)	Bits 0-15: Subcarrier index of the second breakpoint Bits 16-31: *log_tss$_i$* value of the second breakpoint in steps of 0.1 dB
etc.	etc.

The first octet of the descriptor shall contain the number of breakpoints being specified. This number can be zero. In that case, there shall be no further octets in the descriptor, and the field shall be interpreted as all *log_tss$_i$* = 0 for all transmitted subcarriers. If the number of breakpoints is not equal to zero, each group of four consecutive octets shall describe one breakpoint as a *log_tss$_i$* value (see clause 10.3.4.3) at a certain subcarrier index. The *tss$_i$* values shall be determined by the transmitter such that, with combined frequency domain and time domain spectrum shaping, the downstream PSD at the U interface during the training phase and subsequent initialization phases shall be identical to the value MREFPSDds.

The first 16 bits (0-15) in the group of four octets shall contain the index of the subcarrier. The last 16 bits (16-31) shall contain the *log_tss$_i$* value of the subcarrier in dB calculated as specified in clause 10.3.4.3, such that the maximum *log_tss$_i$* value across all breakpoints shall be 0 dB. Each *log_tss$_i$* value shall be an integer multiple of −0.1 dB. The receiver shall obtain the *log_tss$_i$* values for unspecified subcarriers using a linear interpolation between the *log_tss$_i$* values of the assigned breakpoints as specified in clause 10.3.4.3.

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12.3.3.2.2.1 R-MSG 1

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Table 12-33 – Tone descriptor

Octet	Content of field
1	Number of tones
2-5	Bits 0-15: index of tone 1 Bits 16-31: index of tone 2
6-9 (if applicable)	Bits 0-15: index of tone 3 Bits 16-31: index of tone 4
etc.	etc.

The first octet of the tone descriptor shall contain the number of pilot tones selected by the VTU-R. If this number is zero, there shall be no further octets in the descriptor. If the number of tones is not equal to zero, each group of four consecutive octets in the descriptor shall describe the location of two pilot tones.

The first 16 bits (0-15) and the last 16 bits (16-31) in each group of four octets shall contain the indices of two tones. For example, a field value $18000E00_{16}$ means tone $0E00_{16}$ = 3 584 and tone 1800_{16} = 6 144. If the number of pilot tones is odd, the last 16 bits in the field shall be set to ZERO.

Field #6 "Timing advance" indicates the timing advance selected by the VTU-R (which is either the initial value conveyed by the O-SIGNATURE message or a vendor-discretionary setting if no initial value was set by the VTU-O). It shall be expressed either in multiples of 2 samples if profile 35b is used with extended IDFT Size, or otherwise, in samples at the upstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be encoded in a 16-bit field using twos complement format.

• • •

Field #8 "Upstream transmit window length (β_{us})" contains the length of the transmit window that shall be used in the upstream direction during the channel discovery phase. The value shall be expressed either in multiples of 2 samples if profile 35b is used with extended IDFT Size, or otherwise, in samples of the upstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The format shall be the same as for Field #13 of the O-SIGNATURE message (Table 12-21).

Field #9 "Upstream cyclic prefix length" contains the length of the upstream cyclic prefix expressed either in multiples of 2 samples if profile 35b is used with extended IDFT Size, or otherwise, in samples of the upstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be coded as a 16-bit unsigned integer.

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12.3.3.2.2.3 R-PRM

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Field #4 "Upstream cyclic prefix length" contains the value of the cyclic prefix that shall be applied in the upstream direction starting from the beginning of the training phase. The value shall be expressed either in multiples of 2 samples if profile 35b is used with extended IDFT Size, or otherwise, in samples of the upstream sampling rate corresponding to the IDFT size communicated in Field #6. The format of the selected cyclic prefix length shall be the same as for Field #14 of the O-SIGNATURE message (Table 12-21).

NOTE 1 – Profile 35b being used with extended IDFT Size is equivalent with Field #6 having value 14.

NOTE 2 – The value of the CE length used in the calculation of the upstream cyclic prefix length is the value communicated in O-PRM, not the one sent in R-UPDATE.

Field #5 "Upstream transmit window length (β_{us})" contains the length of the transmit window that shall be used in the upstream direction starting from the beginning of the training phase. The value shall be expressed either in multiples of 2 samples if profile 35b is used with extended IDFT Size, or otherwise, in samples of the upstream sampling rate corresponding to the IDFT size communicated in Field #6. The format shall be the same as for Field #13 of the O-SIGNATURE message (Table 12-21).

Field #6 "VTU-R IDFT size" communicates the IDFT size, $2N_{us}$, that shall be used by the VTU-R starting from the beginning of the training phase. The format shall be an 8-bit field coded as $\log_2(2N_{us})$, with valid values from 6 to 14. This value may be different from the initial value that was exchanged during the ITU-T G.994.1 handshake phase.

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12.3.4.2.1.1 O-TA_UPDATE

...

Field #2 "Timing advance correction" defines the timing advance correction that shall be used with respect to the current timing advance. It shall be expressed either in multiples of 2 samples if profile 35b is used with extended IDFT Size, or otherwise, in samples at the upstream sampling rate corresponding to the IDFT size communicated in Field #6 of R-PRM. The value shall be encoded in a 16-bit field using twos complement format. Positive values shall indicate that the transmitted symbol will be advanced more with respect to the received symbol.

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12.3.4.2.2.1 R-TA_UPDATE

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Field #2 "Current timing advance" gives the timing advance currently being used by the VTU-R. The field is expressed either in multiples of 2 samples if profile 35b is used with extended IDFT size, or otherwise, in samples at the upstream sampling rate corresponding to the IDFT size communicated in Field #6 of R-PRM. The value shall be encoded in a 16-bit field using twos complement format.

Field #3 "Timing advance correction" indicates the timing advance correction, with respect to the current timing advance, preferred by the VTU-R either in multiples of 2 samples if profile 35b is used with extended IDFT size, or otherwise, in samples at the upstream sampling rate corresponding to the IDFT size communicated in Field #6 of R-PRM. The value shall be encoded in a 16-bit field using twos complement format. Positive values shall indicate that the transmitted symbol will be advanced more with respect to the received symbol.

Field #4 "Maximum value of timing advance" indicates the maximum value of timing advance that the VTU-R can accommodate either in multiples of 2 samples if profile 35b is used with extended IDFT size, or otherwise, in samples at the current upstream sampling rate corresponding to the IDFT size communicated in Field #6 of R-PRM. The value shall be encoded in a 16-bit field using twos complement format.

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12.3.5.2.1.3 O-PMS

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Table 12-57 – Latency path descriptor

Octet	Field	Format	Description
1	T	1 byte	The number of MDFs in an OH subframe for the latency path; $T = k \times M$, where k is an integer. The value of T shall not exceed 64.
2	G	1 byte	The total number of overhead octets in an OH subframe for the latency path; $1 \leq G \leq 32$.
3	F	1 byte	Number of OH frames in the OH superframe for the latency path. $1 \leq F \leq 255$.
4	M	1 byte	The number of MDFs in an RS codeword for the latency path. Only the values 1, 2, 4, 8, 16 are allowable.
5, 6 and 7	L	3 bytes	Contains the value of L for the latency path.
8	R	1 byte	Contains the value of R for the latency path.
9	I	1 byte	Contains the value of I for the latency path.
10 and 11	D	2 bytes	Interleaver depth D for the latency path.

Table 12-58 – ROC descriptor

Octet	Field	Format	Description
1	T	1 byte	The number of MDFs in an OH subframe of the ROC. $T = k \times M$, where k is an integer. The value of T shall not exceed 64.
2	G	1 byte	The total number of overhead octets in an OH subframe of the ROC; The valid values of G are $1 \leq G \leq 32$.
3	F	1 byte	Number of OH frames in the OH superframe for the ROC. The value of F shall be 1.
4	M	1 byte	The number of MDFs in an RS codeword for the ROC. The valid values of M are 1, 2, 4, 8 and 16.
5, 6 and 7	L	3 bytes	Contains the value of L for the ROC. The valid values of L are from 8 to 128 in multiples of 8.
8	R	1 byte	Contains the value of R for the ROC. The value of R shall be 16.
9	I	1 byte	Contains the value of I for the ROC. I shall be set to $I=M \times (G/T)+R$. The valid values of I are $32 \leq I \leq 66$.
10 and 11	D	2 bytes	Interleaver depth D for the ROC. The valid values of D are $1 \leq D \leq 20$.

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12.3.5.2.1.4 O-PMD

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Table 12-59 – Description of message O-PMD

	Field name	Format
1	Message descriptor	Message code
2	Trellis	1 byte
3	Bits and gains table	$2 \times NSC_{us}$ bytes
4	Tone ordering table	$4 \times \lceil NSC_{us}/2 \rceil$ bytes coded as follows: • Bits 0-15: t_{2n-1} • Bits 16-31: t_{2n}
5	Initialization status	1 byte
6	ITU-T G.998.4 parameter field	Variable length
7	ITU-T G.993.5 parameter field	Variable length
NOTE – The $\lceil x \rceil$ notation represents rounding to the nearest greater integer.		

. . .

Field #4 "Tone ordering table" contains the tone ordering table *t* for the upstream direction. The tone ordering table contains the order in which the subcarriers shall be assigned bits in the upstream direction. The table shall include all subcarriers of the MEDLEYus set and only these subcarriers. Each subcarrier index shall be represented as a 16-bit value. Pairs of subcarrier indices shall be mapped to a field of 4 bytes as shown in Table 12-59. For example, if the value of the n^{th} field is 18001000_{16}, $t_{2n-1} = 1000_{16} = 4\,096$ and $t_{2n} = 1800_{16} = 6\,144$. If the number of subcarriers in the MEDLEYus set is odd, the last 16 bits of the field shall be set to ZERO (and ignored by the receiver). The value of the first index sent shall be equal to the index of the first entry in the tone ordering table (t_1, see clause 10.3.1). The remaining indices shall be sent in increasing order of the tone ordering table *t* entries (t_2, t_3, ... t_{NSCus}).

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12.3.5.2.2.4 R-PMD

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Table 12-65 – Description of message R-PMD

	Field name	Format
1	Message descriptor	Message code
2	Trellis	1 byte
3	Bits and gains table	$2 \times NSC_{ds}$ bytes
4	Tone ordering table	$4 \times \lceil NSC_{ds}/2 \rceil$ bytes coded as follows: • Bits 0-15: t_{2n-1} • Bits 16-31: t_{2n}
5	Showtime pilot tones	Tone descriptor
6	Initialization status	1 byte
7	ITU-T G.998.4 parameter field	Variable length
8	ITU-T G.993.5 parameter field	Variable length
NOTE – The $\lceil x \rceil$ notation represents rounding to the nearest greater integer.		

. . .

Field #4 "Tone ordering table" contains the tone ordering table t for the downstream direction. The tone ordering table contains the order in which the subcarriers shall be assigned bits in the downstream direction. The table shall include all subcarriers of the MEDLEYds set and only these subcarriers. Each subcarrier index shall be represented as a 16-bit value. Pairs of subcarrier indices shall be mapped to a field of 4 bytes as shown in Table 12-65. For example, if the value of the n^{th} field is 18001000_{16}, $t_{2n-1} = 1000_{16} = 4\,096$ and $t_{2n} = 1800_{16} = 6\,144$. If the number of subcarriers in the MEDLEYds set is odd, the last 16 bits of the field shall be set to ZERO (and ignored by the receiver). The value of the first index sent shall be equal to the index of the first entry in the tone ordering table (t_1, see clause 10.3.1). The remaining indices shall be sent in increasing order of the tone ordering table t entries (t_2, t_3, ... t_{NSCds}).

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Q.7 Additional changes to ITU-T G.998.4 for operation according to profile 35b

NOTE – This clause uses revision marks where changes are made relative to the approved text. Unchanged text is replaced by ellipsis (…).

The U reference point specification for operation according to profile 35b shall be the same as specified in [ITU-T G.998.4] for operation with ITU-T G.993.2, with differences listed in this clause.

C.3.2 On-line reconfiguration (OLR) commands and responses

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Table C.11 – OLR commands sent by the initiating VTUName

	Length (octets)	Octet number	Content	Support
Request Type 5 (SRA/ ITU-T G.998.4)	14+4 N_f ($N_f \leq 128$)	2	08_{16}	Mandatory
		3-5	three octets containing the new value for L_1	
		6	one octet containing the new value for B_{10}	
		7	one octet containing the new value for M_1	
		8	one octet containing the new value for R_1	
		9	one octet containing the new value for Q	
		10	one octet containing the new value for V	
		11	one octet containing the new value for Q_{tx}	
		12	one octet containing the new value for lb	
		13 – 14	2 octets for the number of subcarriers N_f to be modified	
		15 – 14+4 N_f	4 N_f octets describing the subcarrier parameter field for each subcarrier	
		15+4 N_f	1 octet for SC	

Table C.11 – OLR commands sent by the initiating VTUName

	Length (octets)	Octet number	Content		Support
Request Type 6 (SOS/ ITU-T G.998.4)	N_{TG}/2+12	2	09_{16}		Optional
		3	Message ID		
		4 to N_{TG}/2+3	$\Delta b(2)$	$\Delta b(1)$	
			$\Delta b(4)$	$\Delta b(3)$	
			…		
			$\Delta b(N_{TG})$	$\Delta b(N_{TG} - 1)$	
		N_{TG}/2+4 to N_{TG}/2+6	three octets containing the new value for L_1		
		N_{TG}/2+7	one octet containing the new value for B_{10}		
		N_{TG}/2+8	one octet containing the new value for M_1		
		N_{TG}/2+9	one octet containing the new value for R_1		
		N_{TG}/2+10	one octet containing the new value for Q		
		N_{TG}/2+11	one octet containing the new value for V		
		N_{TG}/2+12	one octet containing the new value for Q_{tx}		
		N_{TG}/2+13	one octet containing the new value for *lb*		

. . .

Annex R

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Annex S

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Annex T

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Annex U

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Annex V

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Annex X

ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction

(This annex forms an integral part of this Recommendation.)

This annex provides the necessary and sufficient additional requirements for ITU-T G.993.2 operation to allow cancellation of the downstream crosstalk from lines with ITU-T G.993.2 Annex X VTU-Rs into lines with ITU-T G.993.5 VTU-Rs (both connected to ITU-T G.993.5-capable VTU-Os).

This includes:

- Requirements for the ITU-T G.993.2 Annex X VTU-O downstream transmit signals;
- Requirements for the ITU-T G.993.2 Annex X VTU-R downstream receiver to be immune to the ITU-T G.993.2 Annex X VTU-O downstream transmit signals sent by the VTU-O during Initialization and Showtime. The VTU-R shall be immune to the VTU-O sending pilot sequences on the probe tones (as defined in [ITU-T G.993.5]) of the sync symbols during showtime.

A VTU-O supporting operation according to this annex shall also support operation according to [ITU-T G.993.5].

This annex reflects changes to the main body of this Recommendation to allow ITU-T G.993.5-friendly operation of ITU-T G.993.2 in the downstream direction. The clauses below indicate changes to specific clauses of this Recommendation.

NOTE – Simultaneous initialization of a line operating per this annex and a line operating per [ITU-T G.993.5] or per ITU-T G.993.2 Annex O only supports downstream vectoring.

X.1 Power management commands and responses (clause 11.2.3.9)

The same power management commands and responses shall be used as defined in clause 11.2.3.9. The orderly shutdown procedures described in clauses 11.2.3.9.1 and 11.2.3.9.2 shall be modified as defined in this clause.

X.1.1 L3 Request by VTU-R (replaces clause 11.2.3.9.1)

Upon receipt of the L3 Request command, the responding VTU-O shall send either the Grant or Reject response. The proposed link state shall be formatted as 03_{16} for the L3 link state. If any other link state is received, the Reject response shall be sent with the reason code 02_{16}.

The VTU-O may reject a request to move to link state L3 using reason code 01_{16} because it is temporarily busy, or reject it using code 03_{16} because it has local knowledge that the L3 state is not desired at this time.

If the VTU-R receives the Grant response, the VTU-R shall transmit zero power on all subcarriers. The VTU-R shall make no action causing changes to the characteristics of the transmission path. When the VTU-O observes the stopped transmission, it shall also stop transmitting. When the VTU-R observes the stopped transmission, it may perform at its own discretion functions that change characteristics of the transmission path.

X.1.2 L3 Request by VTU-O (replaces clause 11.2.3.9.2)

Upon receipt of the L3 Request command, the responding VTU-R shall send either the Grant or Reject response. The proposed link state shall be formatted as 03_{16} for the L3 link state. If any other link state is received, the Reject response shall be sent with the reason code 02_{16}.

The VTU-R may reject a request to move to link state L3 using reason code 01_{16} because it is temporarily too busy, or reject it using code 03_{16} because it has local knowledge that the L3 state is not desired at this time.

If the VTU-O receives the Grant response, the VTU-O shall transmit zero power on all subcarriers. The VTU-O shall make no actions causing changes to the characteristics of the transmission path. When the VTU-R observes the stopped transmission, it shall also stop transmitting. When the VTU-O observes the stopped transmission, it may perform at its own discretion functions that change characteristics of the transmission path.

X.2 Initialization procedure (supplements clause 12.3)

If and only if the ITU-T G.994.1 VTU-O MS message or VTU-R MS message the NPar(2) bit "ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction" is set to ONE, the VTU-O shall use a modified ITU-T G.993.2 initialization procedure, as defined in this annex.

This initialization procedure is identical to an ITU-T G.993.2 initialization procedure, except for the channel discovery phase and the training phase.

As applicable to the VTU-O, this initialization procedure defines two new signals to be transmitted.

As applicable to the VTU-R, this initialization procedure requires these two new signals to be ignored.

X.2.1 ITU-T G.994.1 handshake phase

X.2.1.1 Handshake – VTU-O

X.2.1.1.1 CL messages (supplements clause 12.3.2.1.1)

Table 12-7 shall be extended with Table X.1 as follows:

Table X.1 – VTU-O CL message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) bit	Definition of NPar(2) bit
ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction	This bit shall be set to ONE, if and only if the VTU-O supports Annex X and Annex X is allowed via the CO-MIB (i.e., VECTORMODE_ENABLE bit 1 is set to 1, see clause 7.3.1.13.9 of [ITU-T G.997.1]). If set to ONE, indicates the capability of the VTU-O to comply with all requirements of this annex, including: • to send O-P-VECTOR-1 (as defined in [ITU-T G.993.5]) during initialization after O-P-QUIET and before O-P-CHANNEL DISCOVERY 1, and • to send O-P-VECTOR-1-1 (as defined in [ITU-T G.993.5]) during initialization after O-P-SYNCHRO 3 and before O-P-TRAINING 1, and • to send pilot sequences on the probe tones (as defined in [ITU-T G.993.5]) of the sync symbols during showtime. If set to ONE, and the CO-MIB VECTORMODE_ENABLE bit 3 is set to 1 (see clause 7.3.1.13.9 of [ITU-T G.997.1]), then the ITU-T G.993.5 SPar(2) bit shall also be set to ONE.

X.2.1.1.2 MS messages (supplements clause 12.3.2.1.2)

Table 12-10 shall be extended with Table X.2 as follows:

Table X.2 – VTU-O MS message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) bit	Definition of NPar(2) bit
ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. If set to ONE, indicates that both the VTU-O and VTU-R shall operate in compliance with all requirements of this annex, including that the VTU-O shall: • send O-P-VECTOR-1 (as defined in [ITU-T G.993.5]) during initialization after O-P-QUIET and before O-P-CHANNEL DISCOVERY 1, and • send O-P-VECTOR-1-1 (as defined in [ITU-T G.993.5]) during initialization after O-P-SYNCHRO 3 and before O-P-TRAINING 1, and • send pilot sequences on the probe tones (as defined in [ITU-T G.993.5]) of the sync symbols during showtime. NOTE – If this bit is set to ONE, bits "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" and "ITU-T G.993.5" are set to ZERO in the VTU-O MS message.

X.2.1.2 Handshake – VTU-R

X.2.1.2.1 CLR messages (supplements clause 12.3.2.2.1)

Table 12-13 shall be extended with Table X.3 as follows:

Table X.3 – VTU-R CLR message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) bit	Definition of NPar(2) bit
ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction	Set to ONE if the VTU-R is compliant with all requirements of this annex, including being immune to a VTU-O • sending O-P-VECTOR-1 (as defined in [ITU-T G.993.5]) after O-P-QUIET and before O-P-CHANNEL DISCOVERY 1, and • sending O-P-VECTOR-1-1 (as defined in [ITU-T G.993.5]) during initialization after O-P-SYNCHRO 3 and before O-P-TRAINING 1, and • sending pilot sequences on the probe tones (as defined in [ITU-T G.993.5]) of the sync symbols during showtime. If set to ONE, the ITU-T G.993.5 SPar(2) bit shall be set to ZERO (see Note).
NOTE – A VTU-R that has ITU-T G.993.5 capability enabled sets this NPar(2) bit to 0.	

X.2.1.2.2 MS messages (supplements clause 12.3.2.2.2)

Table 12-16 shall be extended with Table X.4 as follows:

Table X.4 – VTU-R MS message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) bit	Definition of NPar(2) bit
ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction	Set to ONE if and only if both the last previous CLR and the last previous CL message have set this bit to ONE. If set to ONE, indicates that both the VTU-O and VTU-R shall operate in compliance with all requirements of this annex, including that the VTU-O shall: • send O-P-VECTOR-1 (as defined in [ITU-T G.993.5]) after O-P-QUIET and before O-P-CHANNEL DISCOVERY 1, and • send O-P-VECTOR-1-1 (as defined in [ITU-T G.993.5]) during initialization after O-P-SYNCHRO 3 and before O-P-TRAINING 1, and • send pilot sequences on the probe tones (as defined in [ITU-T G.993.5]) of the sync symbols during showtime. NOTE – If this bit is set to ONE, bits "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" and "ITU-T G.993.5" are set to ZERO in the VTU-R MS message.

X.2.2 Channel discovery phase

X.2.2.1 Overview (supplements clause 12.3.3.1)

Figure X.1 replaces Figure 12-6. Figure X.1 highlights the signals added and the signals/messages modified in the ITU-T G.993.2 channel discovery phase for operation according to this annex. Non-highlighted signals and messages shall be as defined in the main body of this Recommendation.

The VTU-O shall initiate the start of the channel discovery phase with O-P-QUIET 1 as defined in clause 12.3.3.1.

When in the ITU-T G.994.1 VTU-O MS message or VTU-R MS message the NPar(2) bit "ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction" is set to ONE, the VTU-O shall use a modified ITU-T G.993.2 initialization procedure, by insertion of ITU-T G.993.5 O-P-VECTOR 1 of duration no longer than 1 024 × 257 symbols after O-P-QUIET 1.

NOTE – As applicable to the VTU-O, this channel discovery phase is identical to an ITU-T G.993.5 channel discovery phase with all segments x-P-VECTOR y-z set to zero length, except for O-P-VECTOR 1.

After completing the O-P-VECTOR 1 stage, the VTU-O shall start transmitting O-P-CHANNEL DISCOVERY 1 and proceed as defined in clause 12.3.3.1.

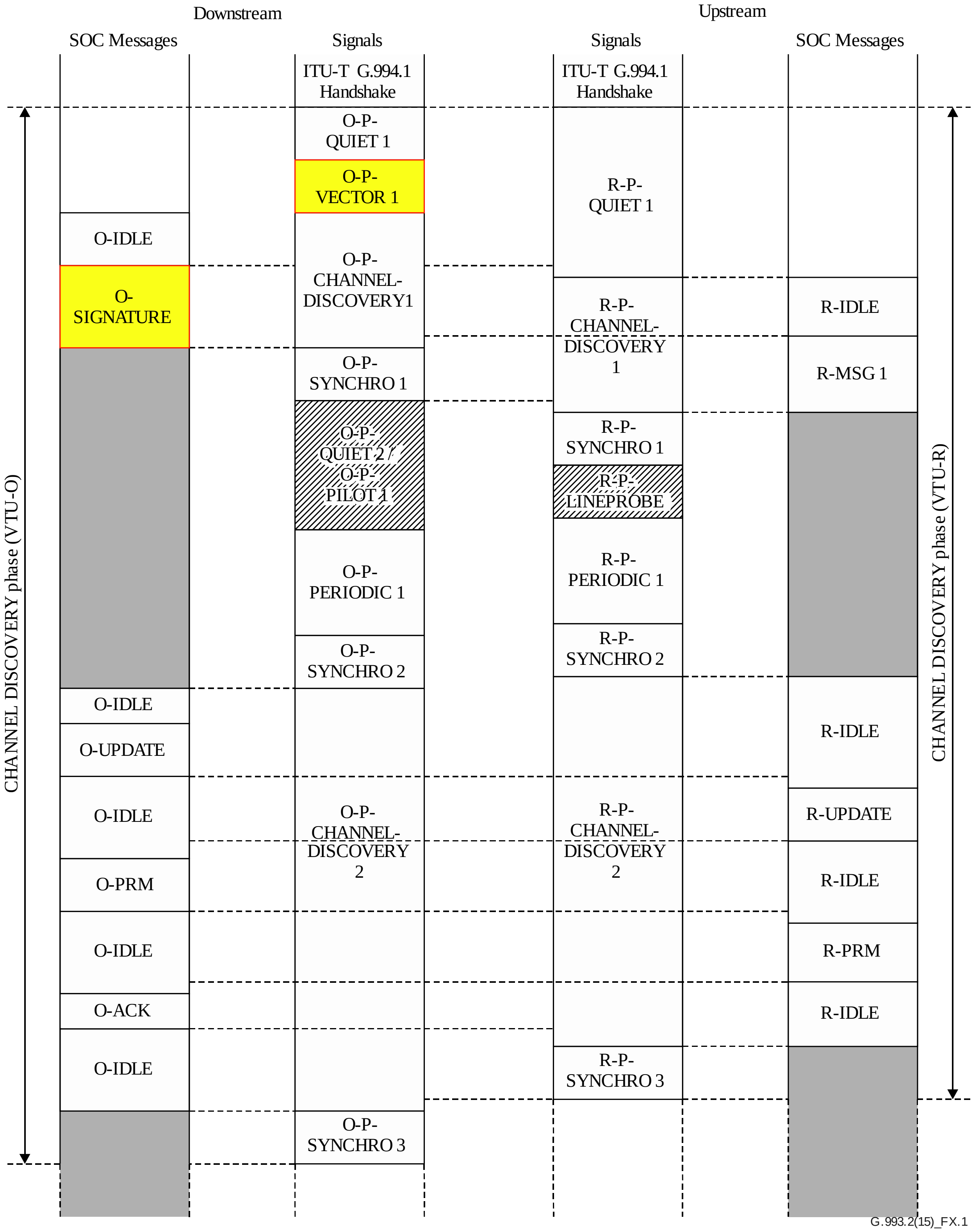

Figure X.1 – Timing diagram for the stages of the channel discovery phase

Table 12-19 shall be extended with Table X.5 as follows:

Table X.5 – VTU-O signals and SOC messages in the channel discovery phase

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages	SOC state
O-P-VECTOR 1	ITU-T G.993.5	4×257 to $1\,024 \times 257$	None	Inactive

X.2.2.1.1 SOC message exchange during the channel discovery phase (supplements clause 12.3.3.2)

X.2.2.1.1.1 VTU-O messages sent during the channel discovery phase (supplements clause 12.3.3.2.1)

X.2.2.1.1.1.1 O-SIGNATURE (supplements clause 12.3.3.2.1.1)

Table 12-21 field #23 shall be replaced with Table X.5a field #23 as follows:

Table X.5a – Description of message O-SIGNATURE

	Field name	Format
23	O-P-VECTOR 1-1 maximum duration	1 byte

Field #23 "O-P-VECTOR 1-1 maximum duration" field indicates the maximum duration of the O-P-VECTOR 1-1 signal, as defined in Table X.6. The three LSBs shall represent the value of *n* in the range 0 to 7 and the five MSBs shall be set to 0.

X.2.2.2 Signals transmitted during the channel discovery phase (supplements clause 12.3.3.3)

O-P-VECTOR 1 shall comply with the general requirements for signals transmitted during the channel discovery phase.

X.2.2.2.1 Signals transmitted by the VTU-O

X.2.2.2.1.1 O-P-VECTOR 1-1 (supplements clause 12.3.4.3.1 preceding clause 12.3.3.3.1.1)

O-P-VECTOR 1-1 shall be as defined in [ITU-T G.993.5].

X.2.2.2.1.2 O-P-VECTOR 1 (supplements clause 12.3.3.3.1 between clauses 12.3.3.3.1.1 and 12.3.3.3.1.2)

O-P-VECTOR 1 shall be as defined in [ITU-T G.993.5].

X.2.2.2.1.3 O-P-SYNCHRO 3 (replaces clause 12.3.3.3.1.9)

O-P-SYNCHRO 3 is a signal that provides an exact time marker for transitions from O-P-CHANNEL DISCOVERY 2 to O-P-VECTOR 1-1 (training phase).

O-P-SYNCHRO 3 shall be identical to O-P-SYNCHRO 1.

X.2.3 Training phase

X.2.3.1 Overview (supplements clause 12.3.4.1)

Figure X.2 replaces Figure 12-8. Figure X.2 highlights the signals added and the signals/messages modified in the ITU-T G.993.2 training phase for operation according to this annex. Non-highlighted signals and messages shall be as defined in the main body of this Recommendation.

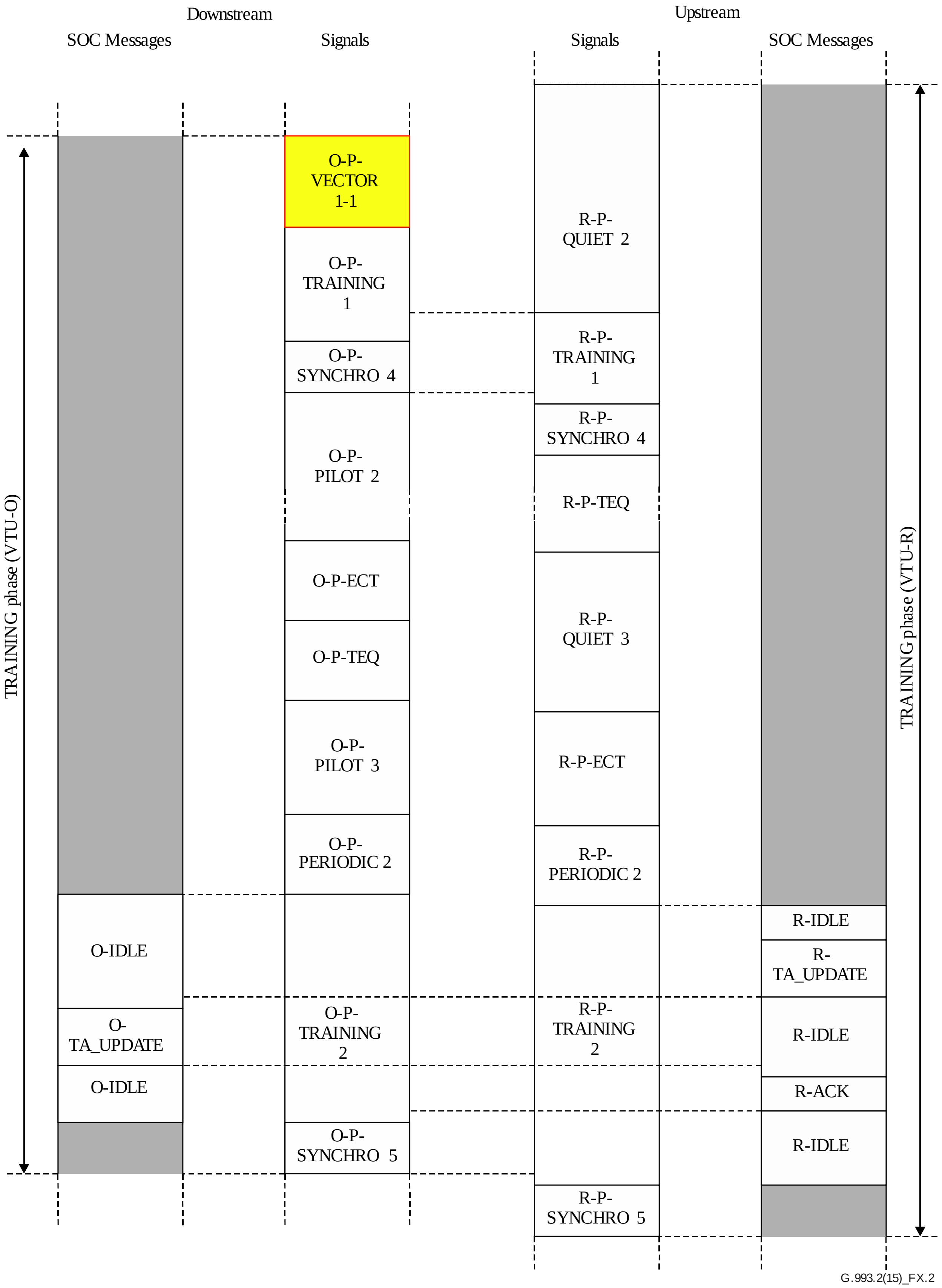

Figure X.2 – Timing diagram for the stages of the training phase

When in the ITU-T G.994.1 VTU-O MS message or VTU-R MS message the NPar(2) bit "ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction" is set to ONE, at the start of the training phase, the VTU-O shall transmit O-P-VECTOR 1-1, and the VTU-R shall be silent (R-P-QUIET 2). O-P-VECTOR 1-1 shall be followed by O-P-TRAINING 1, while the VTU-R is still silent (R-P-QUIET 2). The remainder of the initialization procedure shall be as defined in clause 12.3.4.1.

NOTE – As applicable to the VTU-O, this training phase is identical to an ITU-T G.993.5 training phase with all segments x-P-VECTOR y-z set to zero length except for O-P-VECTOR 1-1.

Table 12-39 shall be extended with Table X.6 as follows:

Table X.6 – VTU-O signals and SOC messages in the training phase

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages	SOC state
O-P-VECTOR 1-1	ITU-T G.993.5	4 × 257 to (*n*+*1*) × 1 024 × 257, with *n*=0…7 (see Note)	None	Inactive
NOTE – The value of *n* is communicated to the VTU-R in O-SIGNATURE message during the channel discovery phase (see Table X.5a).				

X.2.3.2 Signals transmitted during the training phase (supplements clause 12.3.4.3)

O-P-VECTOR 1-1 shall comply with the general requirements for signals transmitted in the training phase.

X.2.3.2.1 Signals transmitted by the VTU-O

Annex Y

Full ITU-T G.993.5-friendly ITU-T G.993.2 operation

(This annex forms an integral part of this Recommendation.)

This annex provides the necessary and sufficient additional requirements for ITU-T G.993.2 operation to allow cancellation of the downstream and upstream crosstalk from lines with ITU-T G.993.2 Annex Y VTU-Rs into lines with ITU-T G.993.5 VTU-Rs (both connected to ITU-T G.993.5-capable VTU-Os that also support upstream vectoring).

NOTE 1 – These requirements also allow cancellation of the upstream crosstalk from lines with ITU-T G.993.5 VTU-Rs into lines with ITU-T G.993.2 Annex Y VTU-Rs (both connected to ITU-T G.993.5-capable VTU-Os).

A VTU-O supporting operation according to this annex shall also support [ITU-T G.993.5] with support of upstream vectoring.

NOTE 2 – Indication of support of ITU-T G.993.5 upstream vectoring in the VTU-O CL message, together with indicating support of ITU-T G.993.2 Annex Y, does not imply a requirement for cancellation of upstream crosstalk from lines with ITU-T G.993.5 VTU-Rs into a line operating according to ITU-T G.993.2 Annex Y.

NOTE 3 – A VTU-R supporting operation according to this annex supports all functionality of ITU-T G.993.5 (including change of the upstream pilot sequence), except for the clipped error sample feedback during initialization (support of R-ERROR-FEEDBACK message is not required) and Showtime (support of the backchannel is not required).

This annex reflects changes to the main body of this Recommendation and [ITU-T G.993.5]. The clauses below indicate changes to specific clauses of Recommendation ITU-T G.993.2 and [ITU-T G.993.5].

Y.1 Initialization procedure (supplements clause 12.3)

If and only if the ITU-T G.994.1 VTU-O MS message or VTU-R MS message the NPar(2) bit "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" is set to ONE, the VTU-O and VTU-R shall use the a modified ITU-T G.993.5 initialization procedure, as defined in this annex. If, in addition, NPar(2) bit "Upstream FDPS in full ITU-T G.993.5-friendly ITU-T G.993.2 operation" is set to ONE, the VTU-O and VTU-R shall also support upstream frequency dependent pilot sequences (FDPS) as defined in ITU-T G.993.5.

This initialization procedure is identical to an ITU-T G.993.5 initialization procedure, except for the initialization messages R-MSG 1, O_TA-UPDATE, and O-PMS and for the initialization signal R-P-VECTOR 2 (during which the message R-ERROR-FEEDBACK is not transmitted).

Y.1.1 ITU-T G.994.1 handshake phase

Y.1.1.1 Handshake – VTU-O

Y.1.1.1.1 CL messages (supplements clause 12.3.2.1.1 of ITU-T G.993.2)

Table 12-7 shall be extended with Table Y.1 as follows:

Table Y.1 – VTU-O CL message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) bit	Definition of NPar(2) bit
Full ITU-T G.993.5-friendly ITU-T G.993.2 operation	This bit shall be set to ONE, if and only if the VTU-O supports Annex Y and Annex Y is allowed via the CO-MIB (i.e., VECTORMODE_ENABLE bit 2 is set to 1, see clause 7.3.1.13.9 of [ITU-T G.997.1]). If set to ONE, indicates that the VTU-O supports compliance with this annex (full ITU-T G.993.5-friendly ITU-T G.993.2 operation). If set to ONE, and the CO-MIB VECTORMODE_ENABLE bit 3 is set to 1 (see clause 7.3.1.13.9 of [ITU-T G.997.1]), then both the ITU-T G.993.5 SPar(2) bit and the related "Upstream vectoring" NPar(3) bit shall also be set to ONE.
Pilot sequence length multiple of 4 in full ITU-T G.993.5-friendly ITU-T G.993.2 operation	If set to ONE, this bit indicates the VTU-O supports pilot sequence lengths that are a multiple of 4. If set to ZERO, this bit indicates the VTU-O only supports pilot sequence lengths that are a power of 2. If set to ONE, the "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" bit shall also be set to ONE.
Upstream FDPS in full ITU-T G.993.5-friendly ITU-T G.993.2 operation	If set to ONE, indicates that the VTU-O supports upstream FDPS as defined in ITU-T G.993.5 when in full ITU-T G.993.5-friendly ITU-T G.993.2 operation. If set to ONE, the "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" bit shall also be set to ONE.

Y.1.1.1.2 MS messages (supplements clause 12.3.2.1.2 of ITU-T G.993.2)

Table 12-10 shall be extended with Table Y.2 as follows:

Table Y.2 – VTU-O MS message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) bit	Definition of NPar(2) bit
Full ITU-T G.993.5-friendly ITU-T G.993.2 operation	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. If set to ONE, both the VTU-O and VTU-R shall operate as defined in this annex. NOTE – If set to ONE, the bit "ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction" (see Annex X) and the bit "ITU-T G.993.5" are both set to ZERO in the VTU-O MS message.
Pilot sequence length multiple of 4 in full ITU-T G.993.5-friendly ITU-T G.993.2 operation	This bit shall be set to ONE if and only if set to ONE in both the last previous CL message and the last previous CLR message. If set to ONE, this bit indicates that "pilot sequence length multiple of 4" is enabled. If set to ZERO, this bit indicates only pilot sequence lengths that are a power of 2 are enabled. If the "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" bit is set to ZERO in the VTU-O MS message, then this bit shall be ignored by the VTU-R.

Table Y.2 – VTU-O MS message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) bit	Definition of NPar(2) bit
Upstream FDPS in full ITU-T G.993.5-friendly ITU-T G.993.2 operation	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. If set to ONE, both the VTU-O and VTU-R shall operate as defined in this annex and support upstream FDPS. If the "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" bit is set to ZERO in the VTU-O MS message, then this bit shall be ignored by the VTU-R.

Y.1.1.2 Handshake – VTU-R

Y.1.1.2.1 CLR messages (supplements clause 12.3.2.2.1 of ITU-T G.993.2)

Table 12-13 shall be extended with Table Y.3 as follows:

Table Y.3 – VTU-R CLR message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) bit	Definition of NPar(2) bit
Full ITU-T G.993.5-friendly ITU-T G.993.2 operation	If set to ONE, indicates that the VTU-R supports full compliance with this annex (ITU-T G.993.5-friendly ITU-T G.993.2 operation). If set to ONE, the ITU-T G.993.5 SPar(2) bit shall be set to ZERO (see Note).
Pilot sequence length multiple of 4 in full ITU-T G.993.5-friendly ITU-T G.993.2 operation	If set to ONE, this bit indicates the VTU-R supports pilot sequence lengths that are a multiple of 4. If set to ZERO, this bit indicates the VTU-R only supports pilot sequence lengths that are a power of 2. If set to ONE, the "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" bit shall also be set to ONE.
Upstream FDPS in full ITU-T G.993.5-friendly ITU-T G.993.2 operation	If set to ONE, indicates that the VTU-R supports upstream FDPS as defined in ITU-T G.993.5 when in full ITU-T G.993.5-friendly ITU-T G.993.2 operation. If set to ONE, the "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" bit shall also be set to ONE.
NOTE – A VTU-R that has ITU-T G.993.5 capability enabled sets this NPar(2) bit to 0.	

Y.1.1.2.2 MS messages (supplements clause 12.3.2.2.2 of ITU-T G.993.2)

Table 12-16 shall be extended with Table Y.4 as follows:

Table Y.4 – VTU-R MS message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) bit	Definition of NPar(2) bit
Full ITU-T G.993.5-friendly ITU-T G.993.2 operation	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. If set to ONE, both the VTU-O and VTU-R shall operate as defined in this annex. NOTE – If set to ONE, the bit "ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction" (see Annex X) and the bit "ITU-T G.993.5" are both set to ZERO in the VTU-R MS message.

Table Y.4 – VTU-R MS message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) bit	Definition of NPar(2) bit
Pilot sequence length multiple of 4 in full ITU-TG.993.5-friendly ITU-T G.993.2 operation	This bit shall be set to ONE if and only if set to ONE in both the last previous CL message and the last previous CLR message. If set to ONE, this bit indicates that "pilot sequence length multiple of 4" is enabled. If set to ZERO, this bit indicates only pilot sequence lengths that are a power of 2 are enabled. If the "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" bit is set to ZERO in the VTU-R MS message, then this bit shall be ignored by the VTU-O.
Upstream FDPS in full ITU-T G.993.5-friendly ITU-T G.993.2 operation	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. If set to ONE, both the VTU-O and VTU-R shall operate as defined in this annex and support upstream FDPS. If the "Full ITU-T G.993.5-friendly ITU-T G.993.2 operation" bit is set to ZERO in the VTU-R MS message, then this bit shall be ignored by the VTU-O.

Y.2 R-MSG1 (supplements clause 10.3.2.2 of [ITU-T G.993.5])

Field #2, "Maximum number of FEXT estimation symbols per super-frame", defines the maximum number (*Kmax)* of symbols in the super-frame for which the VTU-R supports error sample reporting. The field shall be formatted as an unsigned integer with value *Kmax* = 0.

Field #3, "Support of optional backchannel control parameters", indicate the optional values of control parameters supported by the VTU-R. The field shall be formatted as an unsigned integer with value 00_{16}.

Y.3 O-TA_UPDATE (supplements clause 10.4.2.1 of [ITU-T G.993.5])

Field #2, "Error report control parameters", defines the control parameters for each of the vectored bands indicated in O-SIGNATURE. The VTU-R shall ignore the error report control parameters.

Field #3, "SOC Repetition Factor", defines the SOC repetition factor, 1/R, as set by the VCE. The field shall be represented as an unsigned integer with value 1/R = 10.

Field #4, "FEXT estimation symbols per super-frame", defines the number of symbols (*K*) in the super-frame for which a clipped error sample shall be reported. The field shall be formatted as an unsigned integer with value *K* = 0.

Y.4 R-P-VECTOR 2 (replaces clause 10.4.4.5 of [ITU-T G.993.5])

At sync symbol positions, the R-P-VECTOR 2 signal shall contain sync symbols, modulated as defined for the R-P-VECTOR 1 signal. At other symbol positions, the symbols shall be modulated as for the R-P-TRAINING 2 signal, with the extended SOC channel being established.

Transmission of R-P-VECTOR 2 enables the VCE to estimate upstream FEXT channels from the vectored lines into the initializing line and update the estimates of the upstream FEXT from the initializing lines into the vectored lines.

During the sync symbols, the SOC is in the inactive state. During the other symbols, the SOC is in the active state, and the VTU-R shall transmit the R-IDLE message.

The duration of R-P-VECTOR 2 signal is controlled by the VTU-O. Within 64 symbols after the last symbol of the O-P-SYNCHRO V4 signal, the VTU-R shall end the transmission of the R-P-VECTOR 2 signal.

The R-P-VECTOR 2 signal shall be followed by the R-P-SYNCHRO V2 signal.

NOTE – The R-P-VECTOR 2 signal is identical to the ITU-T G.993.5 R-P-VECTOR 2 signal without extended SOC and with the VTU-R transmitting R-IDLE messages instead of R-ERROR-FEEDBACK messages.

Y.5 O-PMS (supplements clause 10.5.2.1 of [ITU-T G.993.5])

Field #2, "Showtime backchannel encapsulation", defines whether the Showtime backchannel is encapsulated into eoc messages or into Layer 2 Ethernet packets. The VTU-R shall ignore this field.

Field #3, "Layer 2 VCE MAC Address", defines the VCE MAC Address to be used by the NT as MAC destination address in case Layer 2 Ethernet encapsulation is used. The VTU-R shall ignore this field.

Field #4, "Layer 2 Line_ID", defines the Line_ID to be used by the NT in case Layer 2 Ethernet encapsulation is used. The VTU-R shall ignore this field.

Y.6 eoc messages for backchannel configuration (replaces clause 8.1 of [ITU-T G.993.5])

During Showtime, the VTU-O shall not send a backchannel configuration eoc command.

NOTE – At the start of Showtime, the backchannel is inactive. In absence of activation by the VTU-O through a backchannel configuration eoc command, the backchannel remains inactive throughout Showtime.

Y.7 Loop diagnostic mode procedures (replaces clause 12.4)

The loop diagnostic mode procedure is identical to the ITU-T G.993.5 loop diagnostic mode procedure.

Appendix I

Example values of DPBO parameters to protect ADSL2plus for clause C.3

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

This appendix defines example values of DPBO parameters defined in clause 7.3.1.2.13 of [ITU-T G.997.1].

These example values are for reducing crosstalk to ADSL2plus.

The set of breakpoints defining PSDMASKds(t_i, PSD_i) should be monotonic in frequency, i.e., $t_i \le t_{i+1}$ for $0 < i \le 32$, except when the DPBOLFO function is used. An interruption in the monotonic frequency progression indicates that DPBOLFO is requested and that the breakpoints following the interruption are for the DPBOLFO.

NOTE – PSDMASKds in this appendix is the ITU-T G.997.1 parameter that is referred to as MIBMASKds in this Recommendation.

I.1 Example PSD parameters

In this clause, PSD parameters to define PEPSD(f), PSDMASKds(f) and DPBOMPSD(f) are described. In Table I.1, DPBOEPSD, DPBOPSDMASKds(f), DPBOLFO and DPBOMUS are defined.

Table I.1 – PSD parameters of DPBO

	DPBOEPSD **(dBm/Hz)**	***DPBOPSDMASKds*** **(dBm/Hz)**	***DPBOLFO*** **(dBm/Hz)**	***DPBOMUS*** **(dBm/Hz)**
VDSL2 in the building	Limit PSD mask = Table C.5	Limit PSD mask = Table C.9	–100	–100
VDSL2 from the cabinet	Limit PSD mask = Table C.5	Limit PSD mask = Table C.5 or Table C.6		

I.2 Example Cable parameters

In this clause, cable parameters to define PEPSD(f) are exemplified. PEPSD(f) is defined as the following equation:

$$PEPSD(f) = DPBOEPSD(f) - \left(DPBOESCMA + DPBOESCMB \cdot \sqrt{f} + DPBOESCMC \cdot f\right)DPBOESEL$$

In Table I.2, DPBOESCMA, DPBOESCMB and DPBOESCMC are defined.

Table I.2 – E-side cable model

	DPBOESCMA (No-dimension)	**DPBOESCMB ($1/\sqrt{\text{MHz}}$)**	**DPBOESCMC (1/MHz)**
VDSL2 in the building	$-10\text{Log}\left(\dfrac{DPBOESEL + DPBORSEL}{DPBORSEL}\right) \Big/ DPBOESEL$	1	0
VDSL2 from the cabinet			

$DPBOESEL = length(m) \times 1\left(\sqrt{MHz}\right) \times 0.0259\ \left(dB/\left[m\sqrt{MHz}\right]\right)$; with *length* (m) equal to the distance in metres between CO and Cabinet (for Japanese cable).

$DPBORSEL = length(m) \times 1(\sqrt{MHz}) \times 0.0259\ (dB/[m\sqrt{MHz}])$; with *length* (m) equal to the distance in metres between Cabinet and VTU-R (for Japanese cable).

I.3 Example frequency parameters

In this clause, frequency parameters to define a frequency range where DPBO is in action are described. In Table I.3, DPBOFMIN is from which DPBO starts and DPBOFMAX is at which DPBO ends.

Table I.3 – Frequency range of DPBO

	DPBOFMIN **(kHz)**	***DPBOFMAX*** **(kHz)**
VDSL2 in the building	138	2 208
VDSL2 from the cabinet		

Appendix II

Impact of loop and VTU impedance mismatch on the Hlog accuracy

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

This appendix provides a discussion regarding the effects on measured accuracy of Hlog(f) when there is a mismatch between a nominal loop termination impedance of 100 Ω and the actual termination impedance (Z_{VTU}) provided by the VTU. This appendix is meant to provide additional technical details regarding the accuracy requirements for the Hlog($k \times G \times \Delta f$) test parameter.

Figure II.1 shows the reference diagram for computing reference received PSD with a spectrum or network analyzer.

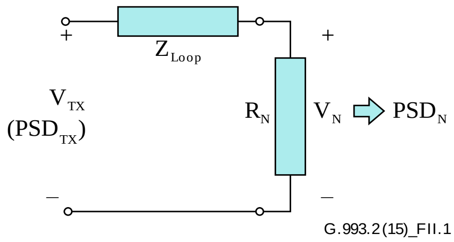

Figure II.1 – Measurement of received PSD by network or spectrum analyzer

Z_{loop} is the impedance of the loop as seen by the network analyzer looking into the test loop. This loop impedance is dependent on the loop topology and may vary with frequency.

R_N is the input impedance of the network analyzer and we assume $R_N = 100\ \Omega$. This value is independent of frequency.

The power spectral density of the received signal as seen by the network analyzer may be represented as:

$$PSD_N = \frac{\left|V_{Tx}\right|^2}{\Delta f} \cdot \frac{R_N}{\left|Z_{loop} + R_N\right|^2} \qquad \text{(II.1)}$$

with Δf representing the subcarrier spacing of 4.3125 kHz.

Figure II.2 shows the reference diagram for computing the PSD received by the VTU.

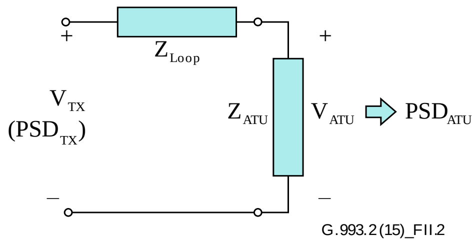

Figure II.2 – Measurement of PSD received by VTU

Z_{loop} is the same loop impedance as for the reference case above in Figure II.1; this is the impedance of the line seen by the VTU looking into the loop.

Z_{VTU} is the input impedance of the VTU as seen by the test loop.

The power spectral density of the received signal as seen by the VTU may be represented as:

$$PSD_{ATU} = \frac{|V_{Tx}|^2}{\Delta f} \cdot \frac{|Z_{ATU}|}{|Z_{loop} + Z_{ATU}|^2} \qquad \text{(II.2)}$$

with Δf representing the subcarrier spacing of 4.3125 kHz.

The difference between equations (II.1) and (II.2) is the error in the receive PSD. Assuming that the transmit PSDs are identical for each case, this difference would represent the error in the Hlog($k \times G \times \Delta f$) measurement. Hence, the Hlog($k \times G \times \Delta f$) error in dB may be represented as follows:

$$Error_{dB} = 10 \cdot \log\left(\frac{PSD_N}{PSD_{ATU}}\right) = 10 \cdot \log\left(\frac{(R_N)}{|Z_{ATU}|} \cdot \frac{|Z_{ATU} + Z_{loop}|^2}{|R_N + Z_{loop}|^2}\right) \qquad \text{(II.3)}$$

The above error expression in dB per equation (II.3) also represents the (contribution of Z_{loop} and Z_{VTU} variation to the) Hlog($k \times G \times \Delta f$) accuracy in dB.

Figure II.3 shows a plot of the Hlog(f) error in dB vs. the VTU input impedance, for different loop impedances that vary from 10 Ω to 200 Ω.

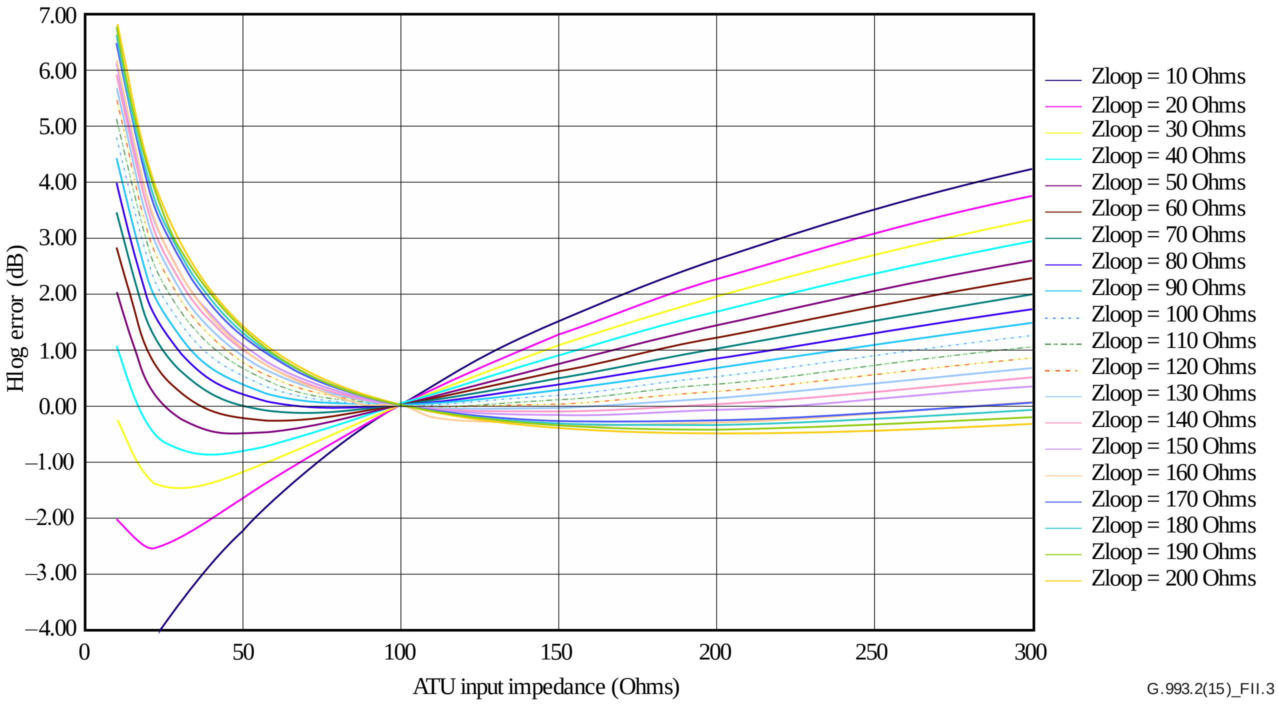

Figure II.3 – Hlog(*f*) error in dB as a function of loop and VTU impedance variations

Regarding the variation of Hlog(f) error with input impedances, the following can be observed:

- This Recommendation does not define any input impedance requirements for VTUs. Similarly, this Recommendation does not define any requirements on return loss. Therefore, VTU implementers are free to design for any input impedance to optimize VTU performance;
- Although it can be observed that the transmit PSD is reported relative to 100 Ω, the loop impedance will generally be different from 100 Ω and the resulting transmit PSD will vary accordingly;
- The VTU input impedance varies among those from different manufacturers;

- The VTU input impedance varies with frequency, which is dependent on implementation;
- If the VTU input impedance is equal to the reference impedance of the network analyzer, i.e., $Z_{VTU} = R_N$, and everything else is perfect, then the error is zero;
- The curves in Figure II.3 do not include any tolerance for components inside the VTU. This tolerance is implementation dependent.

The actual input impedance of a VTU is complex. The impedance values shown in Figure II.3 are the equivalent real Ohmic values.

Bibliography

[b-ATIS-0600023] ATIS-0600023 (2008) – *Guidance for the Use of Upstream Power Back Off Parameters for ITU-T Recommendation G.993.2 Annex A.*

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