International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.993.2

Amendment 2

(02/2008)

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

Digital sections and digital line system – Access networks

Very high speed digital subscriber line transceivers 2 (VDSL2)

Amendment 2

Recommendation ITU-T G.993.2 (2006) – Amendment 2

ITU-T

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

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

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

Recommendation ITU-T G.993.2

Very high speed digital subscriber line transceivers 2 (VDSL2)

Amendment 2

Summary

This amendment to Recommendation ITU-T G.993.2 provides support for an optional impulse noise monitor function and an optional equalized FEXT UPBO method.

Source

Amendment 2 to Recommendation ITU-T G.993.2 (2006) was approved on 6 February 2008 by ITU-T Study Group 15 (2005-2008) under Recommendation ITU-T A.8 procedure.

FOREWORD

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

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

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

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

NOTE

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

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

INTELLECTUAL PROPERTY RIGHTS

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

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

Recommendation ITU-T G.993.2

Very high speed digital subscriber line transceivers 2 (VDSL2)

Amendment 2

1 To support equalized FEXT UPBO, revise clause 7.2.1.3, Table 12-3 in clause 12.3.2.1.1, Table 12-6 in clause 12.3.2.1.2, Table 12-9 in clause 12.3.2.2.1, Table 12-12 in clause 12.3.2.2.2 and clause 12.3.3.2.1.1 (O-SIGNATURE) as follows:

7.2.1.3 Upstream power back-off (UPBO)

Upstream power back-off (UPBO) shall be performed by the VTU-R to improve spectral compatibility between VDSL2 systems on loops of different lengths deployed in the same binder. This UPBO mechanism does not apply during the G.994.1 handshake phase. In addition, UPBO for US0 is for further study.

7.2.1.3.1 Power back-off mechanism

The VTU-R transmit PSD shall be reduced in a frequency-dependent manner using the procedure defined below:

- The transmit PSD mask, PSDMASKus, for the VTU-R shall be calculated by the VTU-O to comply with settings from the network management system as defined in clause 7.2.1. PSDMASKus is communicated to the VTU-R at the beginning of initialization (in O-SIGNATURE).
- The VTU-R shall perform UPBO as described in clause 7.2.1.3.2 autonomously, i.e., without sending any significant information to the VTU-O until the UPBO is applied.
- After UPBO has been applied, the VTU-O shall be capable of adjusting the transmit PSD selected by the VTU-R; the adjusted transmit PSD shall be subject to the limitations given in clause 7.2.1.3.2.

7.2.1.3.2 Power back-off PSD mask

The VTU-R shall explicitly estimate the electrical length of its loop, kl_0, and use this value to calculate the UPBO PSD mask, UPBOMASK, at the beginning of initialization. The VTU-R shall then adapt its transmit signal to conform strictly to the mask UPBOMASK(kl_0, f) during initialization and showtime, while remaining below the PSDMASKus limit determined by the VTU-O as described in clause 7.2.1.3.1, and within the limit imposed by the upstream PSD ceiling (CDMAXMASKus, MAXMASKus).

Two methods for upstream power back-off method are defined:

– the Reference PSD UPBO method;

– the Equalized FEXT UPBO method (optional).

The VTU-C and VTU-R shall support the reference PSD UPBO method, and may support the equalized FEXT UPBO method. If the equalized FEXT UPBO method is supported, it shall be supported for all upstream bands (except US0). This latter method is controlled via the parameter UPBO reference electrical length kl_{0_REF}, which is specified for each upstream band (see Table 12-20.1).

If the optional equalized FEXT UPBO method is not supported, or if the optional equalized FEXT UPBO method is supported but $kl_{0\_REF} = 0$ for a given upstream band, the UPBOMASK for that given band is calculated as:

$$\text{UPBOMASK}(kl_0, f) = \text{UPBOPSD}(f) + \text{LOSS}(kl_0, f) + 3.5 \quad \text{[dBm/Hz]},$$

where:

$$\text{LOSS}(kl_0, f) = kl_0\sqrt{f} \quad \text{[dB], and}$$

$$\text{UPBOPSD}(f) = -a - b\sqrt{f} \quad \text{[dBm/Hz]}$$

where:

with f expressed in MHz.

UPBOPSD(f) is a function of frequency but is independent of length and type of loop.

If the optional equalized FEXT UPBO method is supported, and $kl_{0\_REF} \neq 0$ for a given upstream band, the UPBOMASK for that given band is calculated as:

- for ($1.8 \le kl_0 < kl_{0\_REF}$):

$$UPBOMASK(f) = -a - b\sqrt{f} + 10\log_{10}\left(\frac{kl_{0\_REF}}{kl_0}\right) + LOSS(kl_0, f) + 3.5 \quad \text{[dBm/Hz]}$$

- for ($kl_0 < 1.8$):

$$UPBOMASK(f) = -a - b\sqrt{f} + 10\log_{10}\left(\frac{kl_{0\_REF}}{1.8}\right) + LOSS(1.8, f) + 3.5 \quad \text{[dBm/Hz]}$$

- for ($kl_0 \ge kl_{0\_REF}$):

$$UPBOMASK(f) = -a - b\sqrt{f} + LOSS(kl_0, f) + 3.5 \quad \text{[dBm/Hz]}$$

where:

$$LOSS(kl_0, f) = kl_0\sqrt{f} \quad \text{[dB]}$$

with f expressed in MHz.

For both methods of UPBO, Tthe values of a and b, which may differ for each upstream band, are obtained from the CO-MIB as specified in ITU-T Rec. G.997.1 [4] and shall be provided to the VTU-R during initialization (see 12.3.3.2.1.1). Specific values may depend on the geographic region (Annex A.2.3, Annex B.2.6, and Annex C.2.1.4).

For the optional equalized FEXT UPBO method, the value kl_{0_REF} is obtained from the CO-MIB as specified in ITU-T Rec. G.997.1 [4] and shall be provided to the VTU-R during initialization (see 12.3.3.2.1.1).

If the estimated value of kl_0 is smaller than 1.8, the modem shall be allowed to perform power back-off as if kl_0 were equal to 1.8. The estimate of the electrical length should be sufficiently accurate to avoid spectrum management problems and additional performance loss.

NOTE 1 – A possible estimate of kl_0 is min[loss(f)/$\sqrt{f}$]. The minimum is taken over the usable VDSL2 frequency band above 1 MHz. The function *loss* is the insertion loss in dB of the loop at frequency *f*. This definition is abstract, implying an infinitely fine grid of frequencies.

NOTE 2 – To meet network-specific requirements, network management may provide a means to override the VTU-R's autonomous estimate of kl_0 (see 12.3.3.2.1.2, O-UPDATE).

NOTE 3 – The nature of coupling between loops in a cable binder results in a rapidly decreasing FEXT as the loop length decreases. As the electrical length kl_0 of the loop decreases below 1.8, no further increase in power back-off is needed. An electrical length of 1.8 corresponds to, for example, a 0.4 mm loop about 70 m long.

12.3.2.1.1 CL messages

Table 12-3/G.993.2 – VTU-O CL message NPar(2) bit definitions

G.994.1 NPar(2) Bit	Definition of NPar(2) bit
All-digital mode	If set to ONE, signifies that the VTU-O supports all-digital mode.
Support of downstream virtual noise	If set to ONE, signifies that the VTU-O supports the use of the downstream virtual noise mechanism.
Lineprobe	Always set to ONE in a VTU-O CL message.
Loop diagnostic mode	Set to ONE if the VTU-O requests loop diagnostic mode.
Support of PSD shaping in US0	Always set to ONE in a VTU-O CL message.
Support of equalized FEXT UPBO	If set to ONE, signifies that the VTU-O supports equalized FEXT UPBO.

12.3.2.1.2 MS messages

Table 12-6/G.993.2 – VTU-O MS message NPar(2) bit definitions

G.994.1 NPar(2) Bit	Definition of NPar(2) bit
All-digital mode	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 the VTU-R shall be configured for operation in all-digital mode.
Support of downstream virtual noise	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the downstream virtual noise mechanism may be used.
Lineprobe	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the channel discovery phase of initialization shall include a lineprobe stage.
Loop diagnostic mode	Set to ONE if either the last previous CLR or the last previous CL message has set this bit to ONE. Indicates that both VTUs shall enter loop diagnostic mode.
Support of PSD shaping in US0	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the VTU-R supports PSD shaping in the US0 band.
Support of equalized FEXT UPBO	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that both the VTU-O and the VTU-R shall use equalized FEXT UPBO.

12.3.2.2.1 CLR messages

Table 12-9/G.993.2 – VTU-R CLR message NPar(2) bit definitions

G.994.1 NPar(2) Bit	Definition of NPar(2) bit
All-digital mode	If set to ONE, signifies that the VTU-R supports all-digital mode.
Support of downstream virtual noise	If set to ONE, signifies that the VTU-R supports the use of the downstream virtual noise mechanism.
Lineprobe	Set to ONE if the VTU-R requests the inclusion of a lineprobe stage in initialization.
Loop diagnostic mode	Set to ONE if the VTU-R requests loop diagnostic mode.
Support of PSD shaping in US0	If set to ONE, signifies that the VTU-R supports PSD shaping in the US0 band.
Support of equalized FEXT	If set to ONE, signifies that the VTU-R supports equalized FEXT UPBO.

12.3.2.2.2 MS messages

Table 12-12/G.993.2 – VTU-R MS message NPar(2) bit definitions

G.994.1 NPar(2) Bit	Definition of NPar(2) bit
All-digital mode	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 the VTU-R shall be configured for operation in all-digital mode.
Support of downstream virtual noise	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the downstream virtual noise mechanism may be used.
Lineprobe	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the channel discovery phase of initialization shall include a lineprobe stage.
Loop diagnostic mode	Set to ONE if either the last previous CLR or the last previous CL message has set this bit to ONE. Indicates that both VTUs shall enter loop diagnostic mode.
Support of PSD shaping in US0	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the VTU-R supports PSD shaping in the US0 band.
Support of equalized FEXT	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that both the VTU-O and the VTU-R shall use equalized FEXT UPBO.

12.3.3 Channel discovery phase

12.3.3.1 Overview

The channel discovery phase is the first phase when VDSL2 signals are exchanged between modems. The following tasks are completed during channel discovery:

- Timing recovery and selection of pilot tone(s);
- Establish communication between the modems over the SOC;

- Exchange information necessary to set up the PSDs for both transmission directions; and
- Verify, adjust and exchange various parameter values necessary to enter the training phase (IDFT sizes, CE length, window length and others).

During the channel discovery phase, if the optional equalized FEXT UPBO method is not supported, the VTU-R shall determine the required UPBO based on the estimation of the electrical length of the loop and on the values of parameters for the UPBO reference PSD (UPBOPSD) it receives from the VTU-O. If the optional equalized FEXT UPBO method is supported, the VTU-R shall use in addition the parameter UPBO reference electrical length (UPBOREFEL) it receives from the VTU-O, to determine the required UPBO. Both VTUs may perform additional PSD cut-back.

NOTE 1 – In regions of the spectrum not expected to be useable in showtime, the transceiver may reduce the value of the PSD from the beginning of Channel Discovery to prevent unnecessary crosstalk into other systems. A VTU may, for example, determine the tones where CDPSD can be reduced based on the received signal level and known transmit level of the G.994.1 [2] tones. A specific mechanism is vendor discretionary.

Figure 12-4 presents the timing diagram for the stages of the channel discovery phase. It gives an overview of the sequence of signals transmitted and the sequence of SOC messages sent by the VTU-O and VTU-R during the channel discovery phase. The two inner columns show the sequences of signals that are transmitted (see 12.3.3.3). The two outer columns show the messages that are sent over the SOC (see 12.3.3.2). The shaded areas correspond to periods of time when the SOC is in its inactive state.

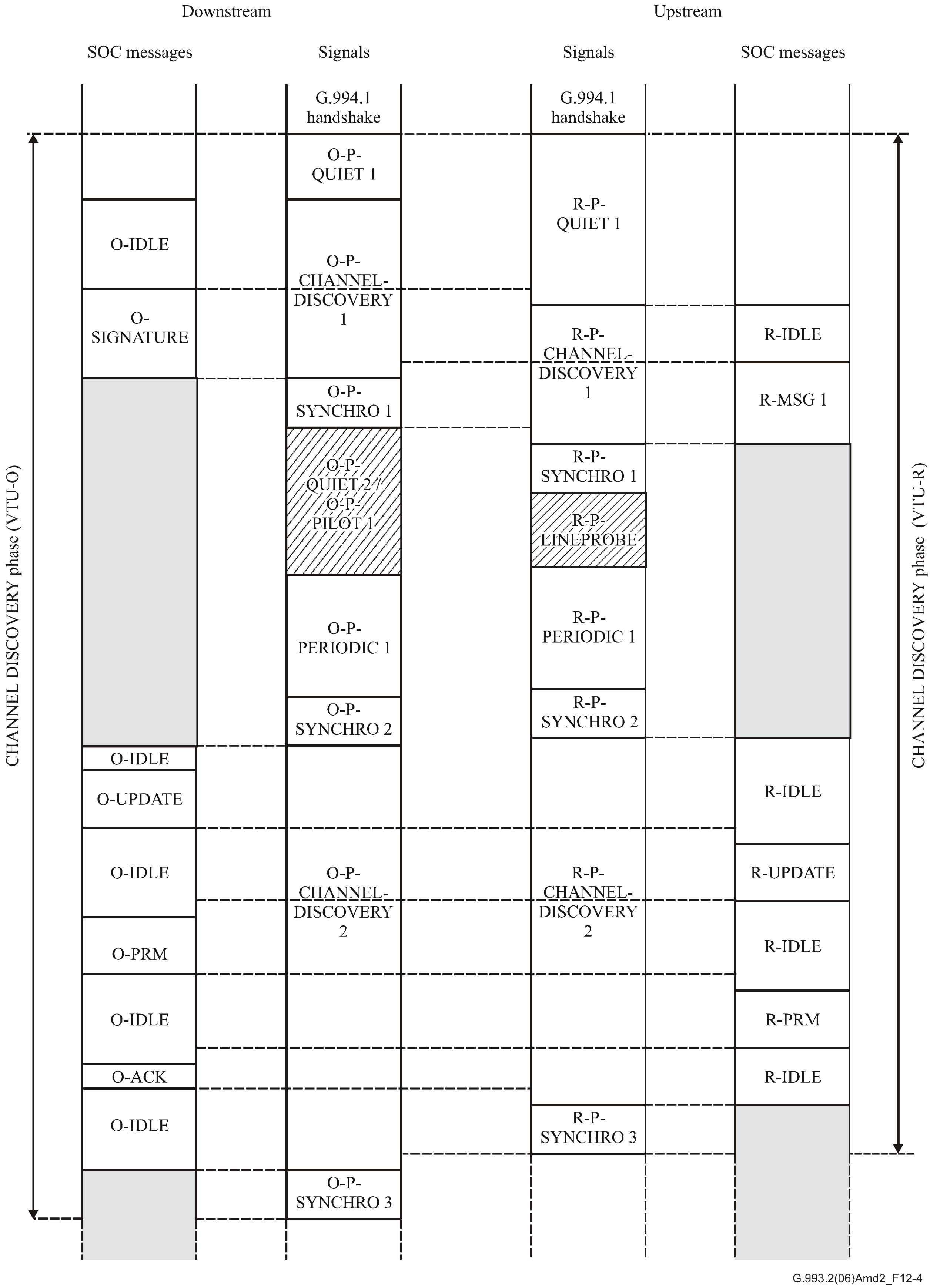

Figure 12-4/G.993.2 – Timing diagram for the stages of the channel discovery phase

NOTE ~~1~~2 – In the exchange of the SOC messages identified in Figure 12-4, the rules of the communication protocol of 12.2.2 apply. Some messages sent in the SOC may require segmentation; although this is not shown in Figure 12-4, the segmented message elements and their corresponding acknowledgements are sent via the SOC per the communication protocol of 12.2.2.

The VTU-O shall initiate the start of the channel discovery phase with O-P-QUIET 1. During this stage, both modems are silent and a quiet line noise measurement can be performed. The duration of O-P-QUIET 1 shall be at least 512 symbols but not longer than 1024 symbols. After completing the O-P-QUIET 1 stage, the VTU-O shall start transmitting O-P-CHANNEL DISCOVERY 1. The VTU-O shall send O-IDLE for a period of between 1500 and 2000 DMT symbols. It shall then send its first message, O-SIGNATURE. O-SIGNATURE shall be sent over the SOC in AR mode, as described in 12.2.2.1, and carries the information listed in Table 12-17.

The VTU-R shall start the channel discovery phase with R-P-QUIET 1 (no signal) until it correctly receives the O-SIGNATURE message. During the R-P-QUIET 1 stage, the VTU-R shall complete the timing lock prior to transmitting R-P-CHANNEL DISCOVERY 1. Upon receiving the O-SIGNATURE message, the VTU-R has all of the necessary information, ~~including the information to compute the UPBO reference PSD (UPBOPSD),~~ needed to perform UPBO (see 7.2.1.3). After performing UPBO, the VTU-R shall transmit R-P-CHANNEL DISCOVERY 1. The VTU-R shall transmit R-P-CHANNEL DISCOVERY 1 using the initial timing advance value received in the O-SIGNATURE message. The VTU-R shall send R-IDLE for at least 512 DMT symbols. It shall then send its first message, R-MSG 1, in AR mode. The VTU-R shall send R-MSG 1 until the VTU-O indicates it has correctly received R-MSG 1. The R-MSG 1 message conveys to the VTU-O the upstream PSD and other VTU-R parameters, as presented in Table 12-24.

The VTU-O shall indicate correct reception of the R-MSG 1 message by transmitting O-P-SYNCHRO 1, which shall be followed by transmission of O-P-PERIODIC 1 if a lineprobe stage is not requested. If a lineprobe stage is requested, the VTU-O shall transmit O-P-QUIET 2/O-P-PILOT 1 and transition to O-P-PERIODIC 1640 symbols after the end of transmission of O-P-SYNCHRO 1. The request for a lineprobe stage is indicated by the parameter "Lineprobe" during the G.994.1 handshake phase (see 12.3.2).

The VTU-R shall reply to O-P-SYNCHRO 1 by transmitting R-P-SYNCHRO 1 within a time period of 64 symbols after detection of O-P-SYNCHRO 1. This shall be followed by transmission of either R-P-PERIODIC 1 if a lineprobe stage is not requested, or R-P-LINEPROBE if a lineprobe stage is requested. The duration of R-P-LINEPROBE shall be 512 symbols. After R-P-LINEPROBE, the VTU-R shall transmit R-P-PERIODIC 1.

The VTU-O shall transmit O-P-PERIODIC 1 for a duration of 2048 symbols and shall then transition to O-P-SYNCHRO 2. The VTU-R shall transmit R-P-PERIODIC 1 for a duration of 2048 symbols and shall then transition to R-P-SYNCHRO 2. During the period of time that O-P-PERIODIC 1 and R-P-PERIODIC 1 are transmitted, the modems may perform SNR measurements.

Immediately after transmission of O-P-SYNCHRO 2, the VTU-O shall transmit O-P-CHANNEL DISCOVERY 2 while sending O-IDLE over the SOC.

After detection of R-P-SYNCHRO 2 and the end of transmission of O-P-SYNCHRO 2, the VTU-O shall send O-UPDATE after a time period of between 48 and 64 symbols, inclusive, to update the parameters of the VTU-R, specifically the PSD of the VTU-R. The O-UPDATE message may also include corrections to the UPBO settings, and additional power cut-back. The parameters conveyed by O-UPDATE are presented in Table 12-21.

The O-UPDATE message and all subsequent SOC messages from the VTU-O shall be sent only once, using the RQ protocol described in 12.2.2.2, which allows the receiving VTU to ask for a retransmission of incorrectly received or missing messages.

The VTU-R shall start transmitting R-P-CHANNEL DISCOVERY 2 immediately after transmission of R-P-SYNCHRO 2, while sending R-IDLE over the SOC. All messages sent by the

VTU-R starting from those sent during R-P-CHANNEL DISCOVERY 2 shall be sent using the RQ protocol described in 12.2.2.2.

After the VTU-R receives the O-UPDATE message, it shall send R-UPDATE to request an update of the downstream PSD and other parameters of the VTU-O, which may include downstream power cut-back. The list of parameters subject to update at the VTU-O and the VTU-R are listed in Table 12-26 and Table 12-21, respectively.

The R-UPDATE message shall be acknowledged by the VTU-O by sending O-PRM over the SOC. O-PRM shall contain the final values of the modulation parameters and PSDs to be used in the training phase. The content of O-PRM is presented in Table 12-22. The VTU-R shall acknowledge O-PRM by sending R-PRM (see Table 12-27), which reports settings of VTU-R modulation parameters, including those requested to be updated in O-UPDATE.

The VTU-O shall acknowledge the reception of the R-PRM message by sending O-ACK. Upon reception of the O-ACK message, the VTU-R shall complete the channel discovery phase in the upstream direction by transmitting R-P-SYNCHRO 3. The VTU-O shall reply by transmitting O-P-SYNCHRO 3 within a time period of 64 symbols. The transmission of O-P-SYNCHRO 3 completes the channel discovery phase in the downstream direction.

All parameter value changes and PSD changes negotiated during the channel discovery phase relative to those indicated in O-SIGNATURE and R-MSG 1 shall be applied in the downstream direction from the first symbol following O-P-SYNCHRO 3 and in the upstream direction from the first symbol following R-P-SYNCHRO 3.

NOTE ~~2~~3 – A change in modulation parameters (such as CE length) may result in the transmission of several corrupt symbols in the downstream direction and a temporary loss of synchronization at the VTU-R receiver. At the start of the training phase, there is a period of time to recover synchronization.

The signals and SOC messages sent by the VTU-O during the channel discovery phase are summarized in Table 12-15, and the signals and SOC messages sent by the VTU-R during the channel discovery phase are summarized in Table 12-16. The protocol used for SOC messages is provided, where applicable, in parentheses in the column labelled "SOC state".

Table 12-15/G.993.2 – 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-QUIET 1	None	512 to 1024	None	Inactive
O-P-CHANNEL DISCOVERY 1	Non-periodic	Variable	O-SIGNATURE	Active (AR)
O-P-SYNCHRO 1	Non-periodic	15	None	Inactive
O-P-PILOT 1	Non-periodic	640	None	Inactive
O-P-QUIET 2	None	640	None	Inactive
O-P-PERIODIC 1	Periodic	2048	None	Inactive
O-P-SYNCHRO 2	Non-periodic	15	None	Inactive
O-P-CHANNEL DISCOVERY 2	Non-periodic	Variable	O-UPDATE, O-PRM, O-ACK	Active (RQ)
O-P-SYNCHRO 3	Non-periodic	15	None	Inactive

Table 12-16/G.993.2 – VTU-R signals and SOC messages in the channel discovery phase

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages	SOC state
R-P-QUIET 1	None	Variable	None	Inactive
R-P-CHANNEL DISCOVERY 1	Non-periodic	Variable	R-MSG 1	Active (AR)
R-P-SYNCHRO 1	Non-periodic	15	None	Inactive
R-P-LINEPROBE	Vendor Discretionary	512	None	Inactive
R-P-PERIODIC 1	Periodic	2048	None	Inactive
R-P-SYNCHRO 2	Non-periodic	15	None	Inactive
R-P-CHANNEL DISCOVERY 2	Non-periodic	Variable	R-UPDATE, R-PRM	Active (RQ)
R-P-SYNCHRO 3	Non-periodic	15	None	Inactive

12.3.3.2.1.1 O-SIGNATURE

The full list of parameters carried by the O-SIGNATURE message is shown in Table 12-17.

Table 12-17/G.993.2 – Description of message O-SIGNATURE

	Field name	Format
1	Message descriptor	Message code
2	Supported sub-carriers in the downstream direction (SUPPORTEDCARRIERSds set)	Bands descriptor
3	Supported sub-carriers in the upstream direction (SUPPORTEDCARRIERSus set)	
4	Downstream transmit PSD mask (PSDMASKds)	PSD descriptor
5	Upstream transmit PSD mask (PSDMASKus)	
6	Channel discovery downstream PSD (CDPSDds)	
7	Initial downstream PSD ceiling (CDMAXMASKds)	2 bytes
8	Downstream nominal maximum aggregate transmit power (MAXNOMATPds)	2 bytes
9	Parameters for UPBO reference PSD (UPBOPSD)	UPBOPSD descriptor
10	Maximum target total data rate	2 bytes
11	Downstream maximum SNR margin (MAXSNRMds)	2 bytes
12	Downstream target SNR margin (TARSNRMds)	2 bytes
13	Downstream transmit window length (β_{ds})	1 byte
14	Downstream cyclic prefix	2 bytes
15	Initial value of timing advance	2 bytes
16	Downstream transmitter referred virtual noise PSD (TXREFVNds)	PSD descriptor
17	SNRM_MODE	1 byte
18	Upstream transmitter referred virtual noise PSD (TXREFVNus)	PSD descriptor
19	UPBO Reference electrical length (UPBOREFEL)	UPBOREFEL descriptor

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-2 for a complete list of codes.

Field #2 "Supported sub-carriers in the downstream direction (SUPPORTEDCARRIERSds)" conveys information about the sub-carriers that are allocated for transmission in the downstream direction. It allows the operator to specify exactly which sub-carriers are available for the downstream direction. No more than 32 bands shall be specified.

Field #3 "Supported sub-carriers in the upstream direction (SUPPORTEDCARRIERSus)" conveys information about the sub-carriers that are allocated for transmission in the upstream direction. It allows the operator to specify exactly which sub-carriers are available for the upstream direction. No more than 32 bands shall be specified.

Fields #2 and #3 shall be formatted as "bands descriptors". The format of the bands descriptor shall be as shown in Table 12-18.

Table 12-18/G.993.2 – Bands descriptor

Octet	Content of field
1	Number of bands to be described
2-4	Bits 0-11: Index of the first sub-carrier in band 1 Bits 12-23: Index of the last sub-carrier in band 1
5-7 (if applicable)	Bits 0-11: Index of the first sub-carrier in band 2 Bits 12-23: Index of the last sub-carrier 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 three consecutive octets in the descriptor shall describe the first and last sub-carrier in a band.

The first 12 bits (0-11) in the group of three octets shall contain the index of the sub-carrier at the lower edge of the band. The last 12 bits (12-23) shall contain the index of the sub-carrier at the upper edge of the band. The first and last sub-carriers shall be included in the band. For example, a field value 400200_{16} means that all sub-carriers from 200_{16} = 512 to 400_{16} = 1024, including sub-carriers 512 and 1024, are included in the set.

Field #4 "Downstream transmit PSD mask (PSDMASKds)" indicates the PSD mask, for both the passband and the stopbands (see 7.2.1, 7.2.2), that is allowed in the downstream direction. The "PSD descriptor" format specified in Table 12-19 shall be used, and the number of sub-carriers being described shall be limited to ≤48. This information shall be taken into account when performing the downstream PSD updates during the channel discovery phase. The VTU-O shall comply with this constraint at all times. In addition, VTU-O shall comply with the requirements in the RFI bands specified during the G.994.1 handshake phase, as specified in 12.3.2.

Field #5 "Upstream transmit PSD mask (PSDMASKus)" indicates the PSD mask, for both the passband and the stopbands (see 7.2.1, 7.2.2), that is allowed in the upstream direction. The "PSD descriptor" format specified in Table 12-19 shall be used, and the number of sub-carriers being described shall be limited to ≤32. This information shall be taken into account when performing the upstream PSD updates during the channel discovery phase. The VTU-R shall comply with this constraint at all times. In addition, the VTU-R shall always comply with the UPBO requirements, which may further reduce the upstream transmit PSD to below the upstream transmit PSD mask, as specified in 7.2.1.3, and with the requirements in the RFI bands specified during the G.994.1 handshake phase, as specified in 12.3.2.

Field #6 "Channel discovery downstream PSD (CDPSDds)" indicates the PSD at the U interface in the downstream direction during the channel discovery phase. The "PSD descriptor" format specified in Table 12-19 shall be used, and the number of sub-carriers being described shall be limited to ≤48. The only valid PSD values obtained by the receiver using the interpolation procedure specified are for those sub-carriers that belong to the SUPPORTEDCARRIERSds set, excluding the RFI bands communicated during the G.994.1 handshake phase. PSD values out of this set shall be ignored by the receiver. The valid CDPSDds values shall be at least 3.5 dB below the downstream transmit PSD mask (Field #4) and at least 3.5 dB below the initial downstream PSD ceiling (Field #7). Moreover, the valid values of CDPSDds, either those which are directly communicated or those obtained at the receiver by interpolation, shall not deviate from the actual values of the transmit PSD, as measured in the reference impedance at the U interface, by more than 1 dB.

Table 12-19/G.993.2 – PSD descriptor

Octet	Content of field
1	Number of sub-carriers (or breakpoints) being described
2-4	Bits 0-11: Index of first sub-carrier being described Bits 12-23: PSD level in steps of 0.1 dB with an offset of −140 dBm/Hz
5-7 (if applicable)	Bits 0-11: Index of second sub-carrier being described Bits 12-23: 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 three consecutive octets shall describe one breakpoint as a PSD value at a certain sub-carrier index.

The first 12 bits (0-11) in the group of three octets shall contain the index of the sub-carrier. The last 12 bits (12-23) 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 320400_{16} means a PSD of $320_{16} \times 0.1 - 140 = -60$ dBm/Hz on sub-carrier index $400_{16} = 1024$. The PSD level of intermediate unspecified sub-carriers 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 sub-carrier indices of the specified breakpoints may be either determined by the CO-MIB or vendor discretionary.

NOTE 1 – Breakpoints should be selected such that the PSD between the breakpoints obtained using linear interpolation is sufficiently close to the PSD that is being described.

Field #7 "Initial downstream PSD ceiling (CDMAXMASKds)" indicates the PSD level that is used to impose a ceiling on the downstream transmit PSD mask to form the downstream PSD mask of the signals transmitted during the channel discovery phase, on which the downstream channel discovery PSD (CDPSDds) is based (see Field #6). The field shall be coded as a 16-bit value with the LSB weight of −0.1 dBm/Hz. The valid values are in the range from 0 dBm/Hz to −90 dBm/Hz in 0.1 dB steps.

Field #8 "Downstream nominal maximum aggregate transmit power (MAXNOMATPds)" indicates the maximum wide-band power that the VTU-O is allowed to transmit. The value shall be expressed in dBm (10.3.4.2.1). This field shall be coded as a 9-bit twos complement signed integer with the LSB weight of 0.1 dBm and the valid range from −25.6 dBm to +25.6 dBm. The spare MSBs shall be set to the value of the sign bit.

Field #9 "UPBO reference PSD (UPBOPSD)" contains the parameters to compute the reference PSD that shall be used for the calculation of UPBO as specified in 7.2.1.3. One set of UPBOPSD parameters (a', b') is defined per upstream band. The values of a' and b' are positive and shall be formatted as shown in Table 12-20.

Table 12-20/G.993.2 – UPBOPSD descriptor

Octet	Content of field
1	Number of US bands
2-4	bits 0-11: value of a' for US1 bits 12-23: value of b' for US1
5-7 (if applicable)	bits 0-11: value of a' for US2 bits 12-23: value of b' for US2
...	
$3 \times n_{us} - 1, 3 \times n_{us} + 1$	bits 0-11: value of a' for US(n_{us}) bits 12-23: value of b' for US(n_{us})

The length of the field is variable and depends on the number of upstream bands exchanged during the G.994.1 handshake phase of initialization (n_{us}), except US0. Parameters a' and b' shall be coded as 12-bit unsigned integers. The value of a is obtained by multiplying a' by 0.01 and adding it to 40. The range of values for a is between 40 and 80.96. The value of b is obtained by multiplying b' by 0.01. This allows values of b between 0 and 40.96 (see 7.2.1.3.2). For those upstream bands in which UPBO shall not be applied, all 12 bits representing values a' and b' shall be set to ZERO (which corresponds to $a = 40$, $b = 0$).

NOTE 2 – The granularity of 0.01 may be finer than needed for practical purposes, but it has been chosen to be able to transmit the values of b specified in regional VDSL standards referred to in ITU-T Rec. G.993.1 [1].

Field #10 "Maximum target total data rate" is the VTU-O's estimate of the maximum downstream total data rate that will be required during the operation of the modem. The VTU-R may use this information to determine the amount of downstream power cut-back (the downstream PSD ceiling) and the spectrum to be used for downstream transmission (e.g., the highest downstream sub-carrier) that is allowed to be used during the channel discovery phase.

NOTE 3 – The CO should determine an appropriate value of the maximum target total data rate based on the configuration parameters of the bearer channels, such as minimum INP (INP_min_n), maximum delay ($delay\_max_n$), and minimum and maximum net data rates (net_min_n, net_max_n), provided in the MIB. The knowledge of the minimum INP and maximum delay can be used to estimate the coding overhead r_n, which is the main factor determining the relation between the net data rate assigned for the bearer channel n and the corresponding total data rate:

$$r_n = \frac{total\_data\_rate_n}{net\_data\_rate_n} \approx 1 + \frac{2 \times INP\_\min_n}{delay\_\max_n \times f_s},$$

where $delay\_max_n$ is in milliseconds and f_s is the data symbol rate in ksymbols/s. Knowledge of the net data rates and of the overhead rates of the bearer channels in use allows the VTU-O to make an estimate of the maximum downstream total data rate.

The field shall be coded as an unsigned integer representing the total data rate as a multiple of 8 kbit/s.

Field #11 "Downstream maximum SNR margin (MAXSNRMds)" indicates the maximum SNR margin the VTU-R receiver shall try to sustain. The definition and use of this parameter shall be the same as for the parameter "downstream maximum noise margin (MAXSNRMds)" specified in ITU-T Rec. G.997.1 [4]. The field shall be formatted as a 16-bit unsigned integer with LSB weight of 0.1 dB and the valid range between 0 and 31 dB. The value of $FFFF_{16}$ shall indicate that no limit on the maximum downstream SNR margin is to be applied (i.e., the maximum value is infinite).

Field #12 "Downstream target SNR margin (TARSNRMds)" indicates the target SNR margin of the VTU-R receiver. The definition and use of this parameter shall be the same as for the parameter "downstream target noise margin (TARSNRMds)" specified in ITU-T Rec. G.997.1 [4]. The format used shall be the same as for Field #11 of the O-SIGNATURE message.

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

Field #14 "Downstream cyclic prefix" shall contain the length of the downstream cyclic prefix expressed in samples at the downstream sampling rate corresponding to the IDFT size communicated during the 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 in samples at the upstream sampling rate corresponding to the IDFT size communicated during the 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.

NOTE 4 – The optimal value of the timing advance is a function of loop length (see 10.4.5.3). The initial value should be applicable for most loop lengths. It is suggested to choose an initial value that corresponds to a loop length of 1500 m. This value can be updated later in the initialization.

Field #16 "Downstream transmitter referred virtual noise PSD (TXREFVNds)" indicates the PSD of the virtual noise in the downstream direction. This information shall be taken into account when determining the SNR margin (for optional SNRM_MODE = 2), which in turn shall be taken into account in determining the possible power cut-back during the channel discovery phase, and for performing the bit loading later in initialization. The "PSD descriptor" format specified in Table 12-19 shall be used, and the number of sub-carriers being described shall be limited to ≤32. When SNRM_MODE = 1, the PSD descriptor field shall contain zero breakpoints (only 1 byte with a value of zero).

Field #17 "SNRM_MODE" indicates the mode of downstream and upstream SNRM computation as described in 11.4.1.1.6. Bits 0 to 3 of the field shall be used to indicate the downstream SNR mode with valid values of 0_{16} (downstream SNRM_MODE = 1, mandatory) and 1_{16} (downstream SNRM_MODE = 2, optional). All other values are reserved. Bits 4 to 7 of the field shall be used to indicate the upstream SNR mode with valid values of 0_{16} (Upstream SNRM_MODE = 1, mandatory) and 1_{16} (Upstream SNRM_MODE = 2, optional). All other values are reserved.

Field #18 "Upstream transmitter referred virtual noise PSD (TXREFVNus)" indicates the PSD of the virtual noise in the upstream direction. The "PSD descriptor" format specified in Table 12-19 shall be used, and the number of sub-carriers being described shall be limited to ≤16. When SNRM_MODE = 1, the PSD descriptor field shall contain zero breakpoints (only 1 byte with a value of zero).

NOTE 5 – Improper setting of TXREFVN can interact with the setting of one or more of the following parameters: maximum net data rate, downstream maximum SNR margin, impulse noise protection, and maximum interleaving delay. This interaction can result in high levels of transmit power that can lead to high crosstalk experienced by DSLs on other pairs in the same binder.

Field #19 "UPBO reference electrical length (UPBOREFEL)" contains the $kl0_{\_REF}$ parameters for the calculation of UPBO according to the optional equalized FEXT UPBO method, as specified in 7.2.1.3. One value of the parameter $kl0_{\_REF}$ is defined per upstream band. The values of $kl0_{\_REF}$ shall be formatted as shown in Table 12-20.1.

The length of the field is variable and depends on the number of upstream bands (n_{us}) exchanged during the G.994.1 handshake phase of initialization, except US0. The value shall be coded as a 16-bit unsigned integer with an LSB weight of 0.1 dB. The valid range of values is from 1.8 to

63.0 dB with a 0.1 dB step, and a special value 0. The use of the special value 0 is described in 7.2.1.3.

Table 12-20.1/G.993.2 – UPBOREFEL descriptor

Octet	Content of field
1	Number of US bands
2-3	bits 0-15: value of $kl0\_{REF}$ for US1
4-5 (if applicable)	bits 0-15: value of $kl0\_{REF}$ for US2
...	
$2 \times n_{us}$, $2 \times n_{us} + 1$	bits 0-15: value of $kl0\_{REF}$ for US(n_{us})

2 Support impulse noise monitor function

To support the impulse noise monitor function, make the following revisions:

2.1 Table 11-4

Modify Table 11-4 in 11.2.3.2 as follows:

Table 11-4/G.993.2 – Low priority commands and responses

Command type and assigned value	Direction of command	Command content	Response content	Support
PMD test parameter read $1000\ 0001_2$	From either VTU to the other	The identification of test parameters for single read, or for multiple read, or for block read	Includes the requested test parameter values or a negative acknowledgment	See Tables 11-25 and 11-26
INM facility $1000\ 1001_2$	From VTU-O to VTU-R	Set or readout the INM data	An acknowledgment of the INM facility set command, or a response including the INM data	Optional
Non-standard facility (NSF) low priority $1011\ 1111_2$	From either VTU to the other	Non-standard identification field followed by vendor proprietary content	An acknowledgment or a negative acknowledgment indicating that the non-standard identification field is not recognized	Mandatory

2.2 New clause 11.4.2.2

Add new clause 11.4.2.2 and subclauses as follows:

11.4.2.2 INM procedure and control parameters

This clause describes the INM procedure and associated INM control parameters.

11.4.2.2.1 INM procedure

Figure 11-5 shows the INM functional block diagram.

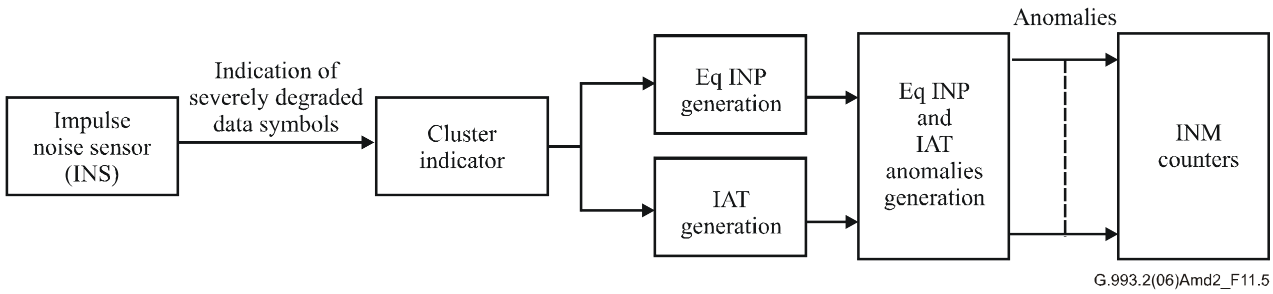

Figure 11-5 – Impulse noise monitor functional block diagram

The impulse noise sensor (INS) indicates whether a data symbol is severely degraded or not. A data symbol is considered to be severely degraded when it would lead to severe errors on the gamma interface when there would be no impulse noise protection (i.e., RS only used for coding gain). The implementation details for this sensor are vendor-discretionary.

NOTE 1 – Performance requirements for the INS are for further study.

If a sync symbol occurs between two data symbols (severely degraded or not), the impulse noise sensor shall disregard it.

NOTE 2 – If a sync symbol occurs between two groups of respectively N1 and N2 consecutive severely degraded data symbols, the two groups will form a single group of consecutive severely degraded data symbols of length N1 + N2 data symbols.

The cluster indicator indicates short groups of severely degraded data symbols as clusters. The cluster can contain a single severely degraded data symbol, a group of consecutive severely degraded data symbols, or several groups of one or more consecutive severely degraded data symbols with gaps between the groups.

The cluster indicator shall use the following rule to identify the cluster. A gap is defined as a group of non-severely degraded data symbols in-between two severely degraded data symbols. A cluster is defined as the largest group of consecutive data symbols, starting and ending with a severely degraded data symbol, containing severely degraded data symbols, separated by gaps smaller than or equal to INMCC (the cluster continuation parameter, see clause 11.4.2.2.4).

As a consequence of the above definition of a cluster, each cluster starts with a severely degraded data symbol preceded by a gap larger than INMCC and ends with a severely degraded data symbol followed by a gap larger than INMCC, while gaps inside the cluster are all smaller than or equal to INMCC.

In the Eq INP generation block, the "equivalent INP" of the cluster is generated. For each cluster, the following characteristics shall be determined:

– The impulse noise cluster length (INCL), defined as the number of data symbols from the first to the last severely degraded data symbol in the cluster.

– The impulse noise cluster degraded data symbols (INCD), defined as the number of severely degraded data symbols in the cluster.

– The impulse noise cluster number of gaps (INCG), defined as the number of gaps in the cluster, with gap as defined above.

Depending on the value of the control parameter INM_INPEQ_MODE, the equivalent INP is generated as:

– INM_INPEQ_MODE = 0: $INP\_eq = INCL$ with INMCC = 0

– INM_INPEQ_MODE = 1: $INP\_eq = INCL$ with INMCC as configured (see 11.4.2.2.4)

– INM_INPEQ_MODE = 2: $INP\_eq = INCD$ with INMCC as configured (see 11.4.2.2.4)

– INM_INPEQ_MODE = 3:

For INCG < (8*erasuregain): $$INP\_eq = \min\left(INCL, ceil\left[INCD * \left(\frac{1}{1-\frac{INCG}{8*erasuregain}}\right)\right]\right)$$

For INCG ≥ (8*erasuregain): $INP\_eq = INCL$

with INMCC as configured (see 11.4.2.2.4)

where the erasuregain is defined as

$$erasuregain = \frac{INP}{INP\_no\_erasure}$$ with INP, and INP_no_erasure as defined in 9.6.

NOTE 3 – In case the bit "INP_no_erasure_required" (bit 8 in the "impulse noise protection and dynamic interleaver reconfiguration" field in Table 12-42, 12.3.5.2.1.1) is set, the erasuregain is equal to 1.

– INM_INPEQ_MODE = 4: In this mode, the value of *INP_eq* shall correspond with the VTU's own estimate (i.e., VTU-R's estimate in the downstream, VTU-O's estimate in the upstream) of the INP_min setting required to provide error-free operation for the cluster, with INMCC as configured (see 11.4.2.2.4). The method of computation of the VTU's own estimate is vendor-discretionary. For INM_INPEQ_MODE = 4 only, if INMCC is set to 64, the VTU shall use its own method for cluster indication. If INMCC < 64, the VTU shall use the cluster indicator as described in this clause for the INM_INPEQ_MODE = 1, 2 and 3.

Anomalies are generated for several values of INP_eq, as defined in 11.3.4.1. The counters of these anomalies represent the INP_eq histogram.

In the IAT generation block, the inter-arrival time (IAT) is generated as the number of data symbols from the start of a cluster to the start of the next cluster. If sync symbols occur between two clusters, they shall not be counted in the IAT. Anomalies are generated for several ranges of inter arrival time, as defined in 11.3.4.3. The counters of these anomalies represent the IAT histogram.

For every data symbol, the total measurement count INMAME is increased by 1.

11.4.2.2.2 Definition of parameter INMIATO

Configuration parameter INMIATO defines the INM inter-arrival time offset for the IAT anomaly generation in order to determine in which bin of the inter-arrival time histogram the IAT is reported (see 11.3.4.3).

The CO MIB shall provide the value for the INMIATO parameter. The parameter in the downstream direction is INMIATOds, and the parameter in the upstream direction is INMIATOus.

The valid values for INMIATO in both directions range from 3 to 511 DMT symbols in steps of 1 DMT symbol. If the VTU supports the INM facility, it shall support all valid values.

Upon entering the first showtime after power-up, the VTU-R shall use a default value of INMIATOds = 3. During showtime, this value may be overwritten by the VTU-O using an INM facility command defined in 11.2.3.13. A link state transition shall not affect the INMIATOds value (e.g., not reset the value to the default value).

The VTU-O shall use the current value of INMIATOus stored in the CO MIB.

11.4.2.2.3 Definition of parameter INMIATS

Configuration parameter INMIATS defines the INM inter-arrival time step for the IAT anomaly generation in order to determine in which bin of the inter-arrival time histogram the IAT is reported (see 11.3.4.3).

The CO MIB shall provide the value for the INMIATS parameter. The parameter in the downstream direction is INMIATSds, and the parameter in the upstream direction is INMIATSus.

The valid values for INMIATS range from 0 to 7 in steps of 1. If the VTU supports the INM facility, it shall support all valid values.

Upon entering the first showtime after power-up, the VTU-R shall use a default value of INMIATSds = 0. During showtime, this value may be overwritten by the VTU-O using an INM facility command defined in 11.2.3.13. A link state transition shall not affect the INMIATSds value (e.g., not reset the value to the default value).

The VTU-O shall use the current value of INMIATSus stored in the CO MIB.

11.4.2.2.4 Definition of parameter INMCC

Configuration parameter INMCC defines the INM cluster continuation value to be used in the cluster indication process described in 11.4.2.2.1. If INM_INPEQ_MODE = 0, INMCC is equal to zero, independent of the CO MIB setting. If INM_INPEQ_MODE > 0, the CO MIB shall provide the value for the INMCC parameter. The parameter in the downstream direction is INMCCds, and the parameter in the upstream direction is INMCCus.

The valid values for INMCC range from 0 to 64 DMT symbols in steps of 1 DMT symbol. If the VTU supports the INM facility, it shall support INMCC = 0. If the VTU supports the INM facility, and supports any INM_INPEQ_MODE > 0, it shall support all valid values.

Upon entering the first showtime after power-up, the VTU-R shall use a default value of INMCCds = 0. During showtime, this value may be overwritten by the VTU-O using an INM facility command defined in 11.2.3.13.

A link state transition shall not affect the INMCCds value (e.g., not reset the value to the default value).

The VTU-O shall use the current value of INMCCus stored in the CO MIB.

11.4.2.2.5 Definition of parameter INM_INPEQ_MODE

Configuration parameter INM_INPEQ_MODE defines the way of computation of equivalent INP, as defined in 11.4.2.2.1. The CO MIB shall provide the value for the INM_INPEQ_MODE parameter. The parameter in the downstream direction is INM_INPEQ_MODEds, and the parameter in the upstream direction is INM_INPEQ_MODEus.

The valid values for INM_INPEQ_MODE are 0, 1, 2, 3 and 4. If the VTU supports the INM facility, it shall support INM_INPEQ_MODE = 0. All other modes are optional. If the VTU supports any INM_INPEQ_MODE > 0, it shall support at least INM_INPEQ_MODE = 1, 2 and 3.

Upon entering the first showtime after power-up, the VTU-R shall use a default value of INM_INPEQ_MODEds = 0. During showtime, this value may be overwritten by the VTU-O using an INM facility command defined in 11.2.3.13.

A link state transition shall not affect the INM_INPEQ_MODE value (e.g., not reset the value to the default value).

The VTU-O shall use the current value of INM_INPEQ_MODEus stored in the CO MIB.

2.3 New clause 11.3.4

Add new clause 11.3.4 and subclauses as follows:

11.3.4 INM primitives

INM-related primitives represent anomalies related to PMD and PMS-TC sub-layers.

11.3.4.1 INM INPEQ histogram primitives

- $INMAINPEQ_1..INMAINPEQ_{16}$: every $INMAINPEQ_i$ is a primitive detected at the near end only. This anomaly occurs when the equivalent INP (as defined in clause 11.4.2.2.1) is exactly *i* DMT symbols.
- $INMAINPEQ_{17}$ is a primitive detected at the near end only. This anomaly occurs when the equivalent INP (as defined in clause 11.4.2.2.1) is strictly more than 16 DMT symbols.

11.3.4.2 INM total measurement primitive

- INMAME: is a primitive detected at the near end only. This indication occurs every time a data symbol is processed by the impulse noise sensor.

11.3.4.3 INM inter-arrival time histogram primitives

- $INMAIAT_0$ is a primitive detected at the near end only. This anomaly occurs when the reported value of IAT falls in the range from 2 to INMIATO-1, both boundaries inclusive.
- $INMAIAT_1..INMAIAT_6$: every $INMAIAT_i$ is a primitive detected at the near end only. This anomaly occurs when the reported value of IAT falls in the range from $(INMIATO + (i - 1)*(2^{INMIATS}))$ to $(INMIATO - 1) + i*(2^{INMIATS})$, both boundaries inclusive.
- $INMAIAT_7$ is a primitive detected at the near end only. This anomaly occurs when the reported value of IAT falls in the range from $INMIATO + 6*(2^{INMIATS})$ to infinity.

2.4 New clause 11.2.3.13

Add new clause 11.2.3.13 as follows:

11.2.3.13 INM facility commands and responses

A VTU that supports the INM facility shall maintain INM counters to measure the impulse noise, as described in ITU-T Rec. G.997.1 [4]. The INM facility commands shall be used to update and read the INM parameters at the VTU-R.

The INM facility command shall be used also to retrieve the current value of the INM counters maintained by the far-end VTU in accordance with ITU-T Rec. G.997.1 [4].

The INM facility commands are described in Table 11-28.2, and may only be initiated by the VTU-O. The VTU-R shall reply using one of the responses shown in Table 11-28.3. The first octet of all INM facility commands and responses shall be the assigned value for the INM facility command type, as shown in Table 11-4. The remaining octets shall be as specified in Table 11-28.2 and Table 11-28.3 for commands and responses, respectively. The octets shall be sent using the format described in 11.2.3.1.

Table 11-28.2/G.993.2 – INM facility commands sent by the VTU-O

Name	Length (Octets)	Octet number	Content
Read INM counters	2	2	02_{16}
Set INM parameters	6	2	03_{16}
		3 to 6	4 octets of INM parameters: see Table 11-28.6
Read INM parameters	2	2	04_{16}
All other values for octet number 2 are reserved by ITU-T.			

Table 11-28.3/G.993.2 – INM facility responses sent by the VTU-R

Name	Length (Octets)	Octet number	Content
ACK	3	2	80_{16}
		3	1 octet INM acceptance code: see Table 11-28.4
NACK	2	2	81_{16}
INM counters	107	2	82_{16}
		3 to 2 + 4 × (17+1+8)	Octets for all of the INM counter values: see Table 11-28.5
		107	1 octet INMDF
INM parameters	6	2	84_{16}
		3 to 6	4 octets of INM parameters: see Table 11-28.6
All other values for octet number 2 are reserved by ITU-T.			

Upon reception of any INM facility command, the VTU-R shall send NACK in response if it does not support the INM procedure or the INM command is invalid. Upon reception of an INM facility set INM parameters command, the VTU-R shall send the ACK in response if it does support the INM procedure.

In case all INM parameter values listed in the set INM parameters command are valid and supported by the VTU-R, the VTU-R shall accept all of the INM parameters contained in the command. The INM acceptance code (see Table 11-28.4) will indicate that the parameters are accepted. If, for any of the INM parameters, the value in the command is different from the value in active use by the INM, the VTU-R shall activate the new INM parameter values and reset the counters less than 1 second after sending the ACK.

In case any INM parameter values listed in the set INM parameters command is valid but not supported by the VTU-R, the VTU-R shall not accept any of the INM parameters and shall not reset the counters.

Upon reception of the INM facility read INM parameters command, the VTU-R shall send the INM parameters response that includes the current value of the VTU-R INM parameters.

Table 11-28.4/G.993.2 – VTU-R INM acceptance code

Name	Octet No.	Content
ACC-INM_INPEQ_MODE	3	80_{16}: value for INM_INPEQ_MODE accepted
NACC-INM_INPEQ_MODE	3	81_{16}: value for INM_INPEQ_MODE not supported

Upon reception of the INM facility read INM counters command, the VTU shall send the INM counters response, which includes the INMDF. Any function of either the requesting or the responding VTU shall not be affected by this command.

The INM counter values shall be derived according to ITU-T Rec. G.997.1 [4] from locally generated defects and anomalies defined within 11.3. The parameters shall be transferred in the order (top to bottom) defined in Table 11-28.5. All counter values are defined as 32-bit counters and shall be mapped to the response in order of most significant to least significant octet.

The INM counters shall be reset at power-up, and shall not be reset upon any link state transition, and shall not be reset upon read. They shall be reset at activation of the new INM parameter values. The reset value is zero. The INM counters and the procedure to update the counters shall work continuously and independently of other (proprietary or non-proprietary) features, e.g., the INM shall work in the presence of OLR and without interruption.

NOTE – The VTU-O should respond to the request from the NMS to read the values of INM counters. It is left to the implementations to store and update the counters as necessary for accurate monitoring and reporting.

Table 11-28.5/G.993.2 – VTU-R INM counters

INM counters
Counter of the $INMAINPEQ_1$ anomalies
Counter of the $INMAINPEQ_2$ anomalies
...
Counter of the $INMAINPEQ_{16}$ anomalies
Counter of the $INMAINPEQ_{17}$ anomalies
Counter of the $INMAIAT_0$ anomalies
Counter of the $INMAIAT_1$ anomalies
...
Counter of the $INMAIAT_6$ anomalies
Counter of the $INMAIAT_7$ anomalies
Counter of the INMAME anomalies

The VTU-R shall set the INM default flag (INMDF) to ONE whenever all active INM parameters are equal to the default values. The VTU-R shall set the INM default flag (INMDF) to ZERO whenever any active INM parameter is different from the default value.

The INM parameter values shall be transferred in the order defined in Table 11-28.6 and mapped in order of most significant to least significant octet.

Table 11-28.6/G.993.2 – VTU-R INM parameters

Octet No.	INM parameter
3-4	2 octets: • The 9 LSBs are INMIATO • The 4 MSBs are INMIATS
5	1 octet: INMCC
6	1 octet: INM_INPEQ_MODE

3 Revised clause 11.2.3.2

Revise clause 11.2.3.2 as follows:

11.2.3.2 Command and response types

With the exception of control parameter read, which is for further study, the VTU shall support all mandatory eoc command and response types specified in Table 11-2 (high priority commands), Table 11-3 (normal priority commands) and Table 11-4 (low priority commands), and their associated mandatory commands and responses specified in 11.2.3.3 to 11.2.3.11, inclusive. The VTU should reply with unable-to-comply (UTC) response on the optional commands that the VTU cannot recognize the assigned value for the command type. The UTC response shall include 2 octets: the first octet of the UTC shall be the same as the first octet of the received command, and the second octet shall be FF_{16}. The UTC is a high priority response.

NOTE – If the UTC response is not supported, the command will time out. This would reduce the efficiency of the eoc.

SERIES OF ITU-T RECOMMENDATIONS

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

Printed in Switzerland
Geneva, 2009