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ITU-T

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OF ITU

G.991.2

Amendment 2
(02/2005)

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

Digital sections and digital line system – Access networks

Single-pair high-speed digital subscriber line (SHDSL) transceivers

Amendment 2

ITU-T Recommendation G.991.2 (2003) – Amendment 2

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ITU-T Recommendation G.991.2

Single-pair high-speed digital subscriber line (SHDSL) transceivers

Amendment 2

Summary

The following text reflects the agreed modification for a second amendment to ITU-T Rec. G.991.2 (2003). The text modifications are shown with revision marks.

Source

Amendment 2 to ITU-T Recommendation G.991.2 (2003) was approved on 22 February 2005 by ITU-T Study Group 15 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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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.

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

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

CONTENTS

ITU-T Recommendation G.991.2

Single-pair high-speed digital subscriber line (SHDSL) transceivers

Amendment 2

1) Modifications to clause 2, References, and to Bibliography in Appendix V

Add the following reference to the list in clause 2:

[12] ITU-T Recommendation I.430 (1995), *Basic user-network interface – Layer 1 specification*.

Add the following references to the Bibliography in Appendix V:

[B17] ETSI TBR 021 (1998-01), *Terminal Equipment (TE); Attachment requirements for pan-European approval for connection to the analogue Public Switched Telephone Networks (PSTNs) of TE (excluding TE supporting the voice telephony service) in which network addressing, if provided, is by means of Dual Tone Multi Frequency (DTMF) signalling*.

[B18] ETSI EN 300 012-1 V1.2.2 (2000-05), *Integrated Services Digital Network (ISDN); Basic User-Network Interface (UNI); Part 1: Layer 1 specification*.

[B19] ETSI EN 300 001 V1.5.1 (1998-10), *Attachments to the Public Switched Telephone Network (PSTN); General technical requirements for equipment connected to an analogue subscriber interface in the PSTN*.

[B20] ETSI EG 201 185 V1.1.1 (1999-02), *Terminal support interface for harmonized analogue PSTN terminals*.

2) Addition to clause 3.2 – "Abbreviations"

Insert the following items to the Abbreviations list in clause 3.2:

BRA Basic Rate Access

e-SHDSL Enhanced SHDSL

3) Modification to clause 6.1.5 – "Power backoff"

Add the following text to the end of clause 6.1.5 after Table 6-2:

In the four-wire mode or M-pair mode, power backoff value PBO-1 shall be assigned to the pair on which the final G.994.1 transaction is conducted. Power backoff value PBO-2 shall be assigned to the remaining pair or pairs.

4) Modification to clause 6.3.1

Add the following Note at the end of clause 6.3.1:

NOTE – For 3 and 4 pairs, the current G.994.1 Annex B method of doing transactions on only one pair has some shortcomings when different parameter values, such as for PBO, might be required on each pair.

5) Modification to clause 6.3.2.1 – "Signal P_{ri}"

In the last paragraph of clause 6.3.2.1, add new text as follows:

In the optional M-pair mode, P_{ri} shall be sent in parallel on all wire pairs. The assignment of power backoff values in 4-wire/M-pair mode shall be as specified in 6.1.5.

6) Modification to clause 6.3.2.2 – "Signal P_{ci}"

In the last paragraph of clause 6.3.2.2, add new text as follows:

In the optional M-pair mode, P_{ci} shall be sent in parallel on all wire pairs. The assignment of power backoff values in 4-wire/M-pair mode shall be as specified in 6.1.5.

7) Modification to clause 6.4.3 – "G.994.1 transactions"

Insert the following new paragraph prior to the last paragraph in clause 6.4.3:

The assignment of power backoff values in 4-wire/M-pair mode shall be as specified in 6.1.5.

8) Modification to clause 11.5 – "Signal transfer delay"

Add the following new paragraph to the end of the text in clause 11.5:

The STU shall be capable of providing PMD-layer one-way, single-span latency of 500 μs or less for user data rates of 1.5 Mbit/s and above, and 1.25 ms or less for user data rates below 1.5 Mbit/s as measured between the α and β interfaces.

M-pair (more than one pair) operation shall add no more than 0.25 ms to the single span latency.

9) Modification to clause A.5.2 – "Return loss"

Revise the text in clause A.5.2 to read as follows:

A.5.2 Return loss

For devices supporting Annex A functionality, return loss shall be specified based on the methodology of 11.3 and the limitations of Figure 11-6. The following definitions shall be applied to the quantities shown in Figure 11-6:

$$RL_{MIN} = 12 \text{ dB}$$

$$f_0 = 12.56 \text{ kHz}$$

$$f_1 = 50 \text{ kHz}$$

$$f_2 = f_{sym}/2$$

$$f_3 = 1.99 f_{sym}$$

where f_{sym} is the symbol rate.

For all Annex F symbol rates greater than 770.67 ksymbol/s, the minimum return-loss requirement shall be identical to the one defined for 770.67 ksymbol/s. The leakage inductance of the line transformer is not a function of the symbol rate. The limitation of the return-loss requirement does not change the performance targets.

10) New clause B.2.4 – "Test loop measurement accuracy"

Add new clause B.2.4 as follows:

B.2.4 Test loop measurement accuracy

The different cable sections of the test loops are specified by two-port cable models that represent real twisted pair cables. Cable simulators as well as real cables can be used to construct these test loops. The associated models and line constants are specified in Appendix II.

The characteristics of each test loop, including those with cascaded sections, shall approximate the models within a specified accuracy. This accuracy specification does not apply to the individual sections.

– The magnitude of the test loop insertion loss shall approximate the insertion loss of the specified models within ± (0.4 dB + 5% of insertion loss) on a dB scale, up to a maximum of 2.1 dB, between F1 and F2, where F1 and F2 are given in Table B.2a.

– The Mean Error (ME) of the test loop insertion loss shall be less than 0.3 dB, and at the same time the Mean Absolute Error (MAE) shall be less than 1.5 dB, between F1 and F2 for transmission in one direction for SHDSL, where F1 and F2 are given in Table B.2a.

– The Mean Error (ME) of the test loop insertion loss shall be less than (*for further study*), and at the same time the Mean Absolute Error (MAE) shall be less than (*for further study*), between F1 and F2 for transmission in one direction for Enhanced SHDSL, where F1 and F2 are given in Table B.2a.

To verify compliance with these ME and MAE requirements, the simulated loop shall be measured over the frequency band from Frequency 1 to Frequency 2 (F1 to F2), where F1 shall be the lowest frequency in the transmission band and F2 shall be the frequency at which the nominal loop attenuation reaches a value at which no signal can be received, or the upper transmission frequency, (as defined in Table B.2a) whichever is lower. Measurements shall be made at N frequencies, separated by equal frequency increments of not more than 10 kHz.

Table B.2a/G.991.2 – Measurement frequency boundaries

	F1	F2
SHDSL	1 kHz	Fsym
e-SHDSL	1 kHz	TBD

The ME and MAE of the measured channel attenuation values in dB, relative to the theoretical loop attenuation values in dB, shall be calculated for the N points measured. Theoretical values of loop attenuation shall be calculated using the RLGC parameters in Appendix II assuming source and load impedances of R_V as defined in B.3.3.2.1.

ME is given by (Attenuation values in dB):

$$\mathrm{ME} = \frac{\left[\sum_{i=1}^{N}\left(ActualAttenuation_i - TheoreticalAttenuation_i\right)\right]}{N}$$

MAE is given by (Attenuation values in dB):

$$\text{ME} = \frac{\left[\sum_{i=1}^{N} \left| ActualAttenuation_i - TheoreticalAttenuation_i \right| \right]}{N}$$

– The magnitude of the test-loop characteristic impedance shall approximate the characteristic impedance of the specified models within ±7% on a linear scale, between frequencies F1 and F2, as given in Table B.2a.

– The group delay of the test loop shall approximate the group delay of the specified cascaded models within ±3% on a linear scale, between frequencies F1 and F2, as given in Table B.2a.

The electrical lengths (insertion loss at specified test frequency) of the test loops, specified in B.2.3, are normative. If the physical length of a test loop implementation is such that *electrical* length is out of specification, its total *physical* length shall be adjusted accordingly to correct this error. This adjustment to the loop-insertion loss by scaling of the physical length should also be used to correct for extra attenuation caused by the noise-injection circuit.

11) Modifications to clause B.3.3.2.1 – "Differential-mode noise calibration"

Amend the text in clause B.3.3.2.1 to read as follows:

B.3.3.2.1 Differential-mode noise calibration

The differential-mode noise injection is calibrated using the configuration shown in Figure B.2b. During calibration the RX side of the noise injector is terminated by the design impedance R_V (= 135 Ω) and the LX (Test Loop interface) side of the noise injector is terminated by an impedance Z_{LX}. The noise levels given in B.3.5 specify the PSD dissipated in R_V on the RX side when Z_{LX} on the LX side is equal to the calibration impedance Z_{cal}. The impedance Z_{cal} is defined in Figure B.2c.

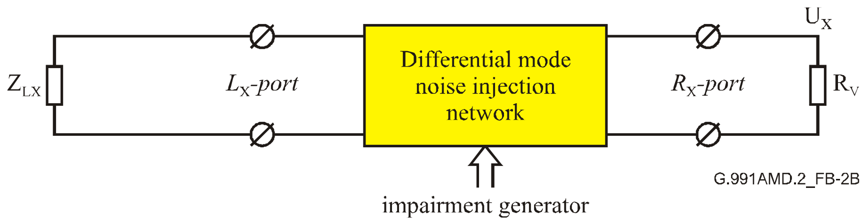

Figure B.2b/G.991.2 – Configuration for noise level calibration

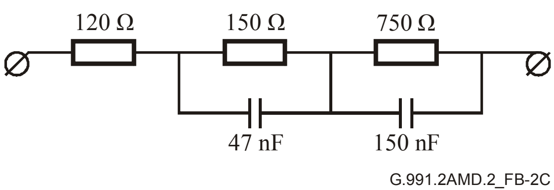

Figure B.2c/G.991.2 – Calibration impedance Z_{cal}

When calibrating the noise source, tThe impedance Z_{LX} on the LX side of the noise injection circuit is equal to the calibration impedance Z_{cal} as given in Figure B.2c. For this case, tThe PSD dissipated in the impedance R_V shall be equal to the differential noise PSD $P_{xn}(f)$ defined in B.3.5.1.

NOTE 1 – This calibration method is theoretically equivalent to the following: For an arbitrary value of the impedance Z_{LX}, the PSD dissipated in R_V from a calibrated source is equal to:

$$P_{cal}(f) = G(f, Z_{LX}) P_{xn}(f)$$

NOTE 2 – For a calibrated noise source this theoretically determined P_X should be identical to the measured PSD dissipated in R_V in the presence of Z_{LX}.

NOTE 3 – The impedance dependent correction factor is specified as:

~~where G(f,Z~~$_{LX}$~~) is the impedance dependent correction factor, which is specified as:~~

$$G(f, Z_{LX}) = \left| \frac{\frac{1}{Z_{cal}} + \frac{1}{Z_{inj}} + \frac{1}{R_v}}{\frac{1}{Z_{LX}} + \frac{1}{Z_{inj}} + \frac{1}{R_v}} \right|^2$$

where Z_{cal} is the calibration impedance given in Figure B.2c, Z_{inj} is the Norton equivalent impedance of the noise injection circuit (see Figure B.2a), and R_V = 135 Ω is the SHDSL design impedance.

The noise-generator gain settings determined during calibration shall be used during performance testing. During performance testing, the noise-injection circuit will be configured as shown in Figure B.2. Because the loop impedance and the impedance of the modem under test may differ from the impedances Z_{LX} and R_V used during calibration, the voltage over the RX port of the modem may differ from the voltage U_X observed during calibration.

12) Edit to clause B.3.4 – "Performance test procedure"

Add the following Note to the end of clause B.3.4 after Table B.3.

NOTE – Table B.3 constitutes a rationalized subset of tests that are considered to be representative of the full set of tests. For conformance, these tests (subset) are required. Other tests (possibly based on other test loops) are under study.

13) New text for clause B.3.5.3.7 – "Impulse noise generator [G7]"

Replace the text in B.3.5.3.7 with the following:

A test with this noise generator is required to prove the burst noise immunity of the SHDSL transceiver. The impulse noise waveform $V(t)$ (hereafter called the "test impulse") is defined as:

$$V(t) = \begin{Bmatrix} K|t|^{-3/4} & t > 0 \\ 0 & t = 0 \\ -K|t|^{-3/4} & t < 0 \end{Bmatrix}$$

where t is time given in units of seconds and K is a constant defined numerically in Table B.5a. If the pulse is realized using discrete samples of $V(t)$, the waveform should be sampled at $t = (2n-1)\frac{T}{2}$, where T is the sampling period and ($1/T$) should be at least twice the symbol rate of the system under test. The sampled peak-to-peak amplitude will vary with sampling rate. It can be calculated using the following formula:

$$V_{p-p} = 2K\left|\frac{T}{2}\right|^{-\frac{3}{4}}$$

Table B.5a/G.991.2 – Impulse noise peak-to-peak voltage requirement

K	**V_{p-p} of the test impulse sampled at 2 Msamples/s**
1.775×10^{-6}	320 mV

For a sampling rate of 2 Msamples/s, a minimum of 8000 samples is required with an amplitude accuracy of at least 12 bits. Figure B.5a shows the test impulse sampled at 2 Msamples/s. The injection circuit shall be identical to that described in B.3.3.1.1.

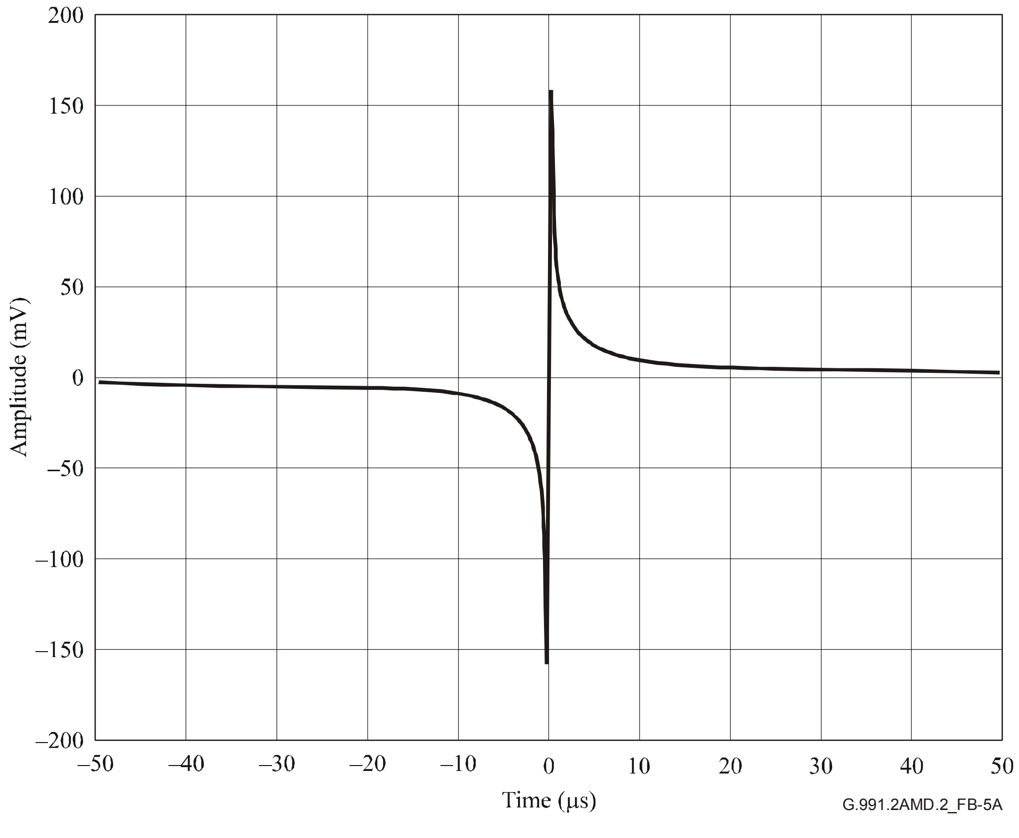

Figure B.5a/G.991.2 – Time domain representation of the test pulse sampled at 2 Msamples/s

A compliant unit shall pass the impulse noise test specified in Table B.5b. The minimum test period shall be 10 s. Each SHDSL termination shall be tested independently, i.e., the impulse noise waveform is not injected at both terminations simultaneously. No other impairment source shall be active during this test.

Table B.5b/G.991.2 – Impulse noise test criteria

Test loop	Test pulse V_{p-p} when sampled at 2 Msamples/s	Test pulse repetition rate	Bit error ratio upper limit
Loop#2	320 mV	10 Hz	9.0×10^{-4}
NOTE 1 – The impulse test is applied to a single pair and the BER limit applies to the pair under test. NOTE 2 – The entries in this table only correctly apply to the 2304-kbit/s symmetric case with the 16 UC PAM constellation. Appropriate values for other rates and PSDs are for further study. NOTE 3 – Test loop length can be determined from Table B.2.			

14) Modification to clause B.5.2 – "Return loss"

Add the following new paragraph at the end of clause B.5.2:

For all Annex G symbol rates greater than 770.67 ksymbol/s, the minimum return loss requirement shall be identical to the one defined for 770.67 ksymbol/s. The leakage inductance of the line transformer is not a function of the symbol rate. The limitation of the return loss requirement does not change the performance targets.

15) Modifications to clause B.5.3.2 – "Power feeding of the STU-R"

Amend the text in clause B.5.3.2 to read as follows:

~~The STU-R shall be able to consume power from the remote power feeding circuit when the local power supply fails.~~

~~NOTE – The remote feeding strategy may not be applicable for extremely long lines or lines including regenerators. In those cases specific feeding methods may be applied, which are for further study.~~

~~The STU-R shall be able to draw up to a maximum of 10 mA as wetting current from the remote feeding circuit when the STU-R is being powered locally. When the local power fails the maximum current drawn by the STU-R from the remote feeding circuit shall be limited to the value specified in IEC 60 950 [7].~~

~~It is optional for the STU-C to provide wetting current.~~

The capability for an STU-R (or a SRU) to be remotely powered over the span is optional. However, if this capability is provided, the STU-R or SRU shall meet the requirements of B.5.3.5 and B.5.3.6.

NOTE – The remote feeding strategy may not be applicable for extremely long lines or lines including regenerators. In those cases, specific feeding methods may be applied, which are for further study.

Requirements for wetting current are given in B.5.3.7.

16) Modification to clause B.5.3.3 – "Power feeding of the interface for narrow-band services"

Add a new sentence to the text in clause B.5.3.3 as follows:

When simultaneous telephone service is provided by the STU-R, feeding of restricted-mode power for life-line service has to be provided for at least one telephone set in case of local power failure. The requirements for ISDN-BRA are described in EN 300 012-1 [B18] and information on power feeding for analogue access is described in EN 300 001 [B19], EG 201 185 [B20] and TBR 021 [B17].

NOTE – The remote-feeding strategy may not be applicable for extremely long lines or lines including regenerators. In those cases, specific feeding methods may be applied which are for further study.

17) Modification to clause B.5.3.4 – "Feeding power from the STU-C"

Revise the text in clause B.5.3.4 as follows:

The feeding power shall be limited to the values specified in IEC 60950 [7] to meet the requirements for TNV-3.~~ The feeding power shall be limited to the values specified by the TNV requirements in IEC 60 950 [7].~~

~~NOTE – This means that the sum of the DC- and AC-voltage at the STU-R may not exceed 120 V. The safety standards may for extraordinary cases with long lines or regenerators allow higher power to be supplied from the STU-C. This is left for further study. It is likely that supporting long lines and/or regenerators may imply floating (not connected to ground) power feeding circuits.~~

18) Modification to clause B.5.3.5 – "Power available at the STU-R"

Delete the text in clause B.5.3.5 and add new clauses B.5.3.5.1 to B.5.3.5.3 as follows:

~~The STU-R shall be able to deal with any polarity. With a minimum voltage of 45 V (see NOTE) at the input of the STU-R, it shall enter a full operational state.~~

~~NOTE – This value depends on the supply voltage and is for further study.~~

~~When remote power feeding is provided by the network, the STU-R and the side of the SRU directed towards the STU-C shall enter a high impedance state within 2 s after interruption of the remote current fed towards the STU-R or the SRU respectively. This state shall be maintained as long as the voltage on the line stays below 18 V (DC + AC peak). In this state the leakage current shall be less than 10 µA and the capacitance shall be greater than 2 µF. A guard time of at least 2 s between removing the remote power and applying a test voltage is necessary.~~

<u>B.5.3.5.1 Static requirements</u>

<u>The STU-R shall be able to deal with any polarity.</u>

<u>The maximum power drawn by the SHDSL STU-R when the local power fails and lifeline service must be provided is 2.1 W.</u>

<u>NOTE – In order to enhance the performances in the critical conditions (longest loops and lower input voltages) and to avoid giving unnecessary burden to the design of the STU-R, compliance to the 2.1 W limit is requested only when the STU-R input voltage is < 70 V. With STU-R input voltages higher than 70 V (short loops and higher STU-R feeding voltages), a power consumption up to 2.5 W is permitted.</u>

<u>B.5.3.5.2 Dynamic requirements</u>

<u>The values given in this clause represent currently used practice of testing dynamic power feeding behaviour.</u>

<u>The test shall be carried out with the test circuit given in Figure B.11.</u>

<u>The current drawn, by the test circuit, from the voltage source shall be below X mA, where X is given in Table B.13a, 1.5 s after switch-on of the feeding voltage.</u>

<u>When the voltage at the STU-R exceeds for a first time 28 V, this voltage limit shall be maintained further on and shall not go below 28 V again.</u>

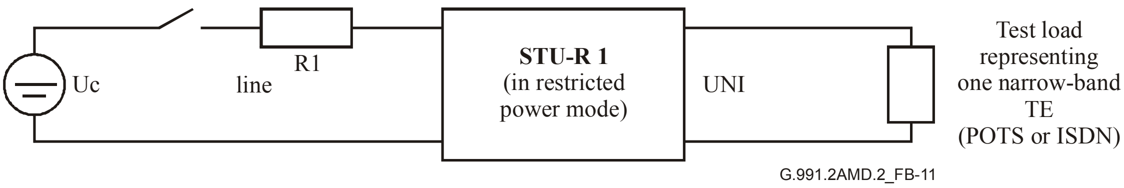

Figure B.11/G.991.2 – Test circuit for STU-R

Table B.13a/G.991.2 – Values of components for STU-R power source test load according to Figure B.11

Voltage range (V)	R1 (Ω)	X (mA)
51-69	283	TBD (see Note)
66-70	473	TBD (see Note)
90-110	880	60
95-99	981	60
107-112	1244	60
NOTE – These values are left for further study.		

B.5.3.5.3 Reset of STU-R

The STU-R, independently from the operating condition such as feeding voltage, line resistance, active/deactivated state and power drawn by the user/network interface, shall enter a reset state (i.e., physical reset of the line transceiver) no later than 2 s after interruption of the remote current fed towards the STU-R.

19) New clauses B.5.3.6 – "DC and low frequency AC termination of STU-R" and B.5.3.7 – "Wetting current"

Add the following new clauses B.5.3.6 and B.5.3.7 after clause B.5.3.5:

B.5.3.6 DC and low frequency AC termination of STU-R

When remote power feeding is provided by the network, the STU-R and the side of the SRU directed towards the STU-R shall enter a high-impedance state within 2 s after interruption of the remote current fed towards the STU-R or the SRU respectively. This state shall be maintained as long as the voltage on the line stays below 18 V (DC + AC peak). In this state, the leakage current shall be less than 10 μA and the capacitance shall be greater than 2 μF.

B.5.3.7 Wetting current

If the STU-R is not powered by the span, wetting current may be used, with the intention to maintain low splice-resistance in outside plant environments. The support of wetting current by the STU-C is optional. Sinking of wetting current by the STU-R is mandatory.

Due to the limited power available at remote locations, regenerators are not required to source wetting current, but shall be able to sink wetting current.

If wetting current support is implemented, at least one of the methods defined in B.5.3.7.1 and B.5.3.7.2. must be implemented.

The method in B.5.3.7.1 is intended for applications in coexistence with remote power feeding. The remote power source is used as the wetting current source. A current sink at the STU-R uses the remote feeding voltage present at the STU-R when locally powered. In case of a local power failure at the STU-R, the STU-R could draw power from the same source.

The method in B.5.3.7.2 is intended for environments with the absence of remote power feeding. The battery voltage at the STU-C is directly used in combination with, e.g., series resistors to provide wetting current. This method is also intended to be interoperable with equipment implementing the requirements of Annex A for wetting current.

B.5.3.7.1 Wetting current implementation in coexistence with remote power feeding

If wetting current is supported, the STU-C shall apply a constant voltage to the wire pair, while the STU-R uses a current sink for the DC voltage arriving at the STU-R.

B.5.3.7.1.1 STU-C

The STU-C shall present a DC voltage of 96 V to 120 V on the line if wetting current is used. The DC voltage source shall operate at least from 0 mA to 10 mA of load current for the purpose of wetting current. If the voltage source is not isolated from ground potential, the DC voltage at the line terminals shall be negative towards ground.

B.5.3.7.1.2 STU-R

The STU-R shall be capable of drawing between 1.0 mA and 10 mA of wetting (sealing) current from the DC voltage on the line presented at its terminals in the case when the STU-R is not span-powered and the wetting current sink is enabled at the STU-R. In the case of a multi-pair span, the wetting current range applies to the average current of all lines, allowing a single common wetting current sink for all wire pairs of a span. The voltage at the terminals of the STU-R can range from 60 V to 120 V. The wetting current sink, and the line terminals it is connected to, should be isolated from other electrical parts. The operation of the wetting current sink shall be independent of the polarity of the voltage applied at the line terminals.

NOTE 1 – The actual current will depend on the implementation of the wetting current sink (e.g., resistive or constant current-sink), the DC source voltage at the STU-C and the loop resistance. In the case of a multi-pair span with a common current sink, the wetting current is distributed over the individual pairs by the parallel connection of the loop resistances.

NOTE 2 – STU-R and STU-C have to conform to the applicable safety regulations. For the case of IEC 60950 [7], the line has to be classified as a "TNV-3 circuit" with a "working voltage" of up to 120 V. This requires a "reinforced isolation" from the line to "SELV" circuits (typical for application interface). Other regulations may require the implementation of a current limitation for the STU-C voltage source.

NOTE 3 – The 10mA current limit is not derived from any electrical-safety specification. Its aim is to limit the power budget delivered by the network when wetting current is applied.

B.5.3.7.2 Wetting current implementation in absence of remote power feeding

The generation of wetting current at the STU-C is optional. The ability of sinking wetting current at the STU-R is mandatory.

B.5.3.7.2.1 Wetting current source at the STU-C side

The open-circuit voltage at the STU-C shall be in the range from 35 V to 72 V. If the voltage source is not isolated from ground potential, the DC voltage at the line terminals shall be negative towards ground. The short circuit current of the source at the STU-C shall be 20 mA at maximum. The output current of the source shall be higher or equal than the theoretical output current of a 35 V voltage source with a 18-kΩ series resistor under all load conditions.

NOTE – A source implementation according to these requirements is intended to be compliant with A.5.3.3.

B.5.3.7.2.2 Wetting current sink at the STU-R side

Under normal operating conditions, the wetting current sink shall expect a maximum voltage at the NTU input of 72 V and a maximum current of 20 mA. When the current sink at the NTU is enabled, the current drawn should be higher than or equal to the theoretical value of the current drawn by a 15-kΩ resistor. The operation of the wetting current sink shall be independent of the polarity of the voltage applied at the line terminals. The wetting current sink and the line terminals it is connected to should be isolated from other electrical parts.

To help ensure that a low splice resistance is maintained at all times, the NTU shall implement a passive wetting current sink circuit such that it sinks the current even when its circuitry is powered off for whatever reason.

NOTE 1 – The combination of the 15-kΩ limit at the STU-R and the 18-kΩ limit at the STU-C guarantees a wetting current greater than 1 mA with a open-circuit voltage of 35 V.

NOTE 2 – The 15-kΩ limit is met by a metallic termination according to A.5.3.4 after being switched in the "ON"-state by the open circuit voltage.

NOTE 3 – STU-R and STU-C have to conform to the applicable safety regulations. In case of IEC 60950 [7], the line has to be classified as a "TNV-3 circuit" with a "working voltage" of up to 72 V. This requires "reinforced isolation" from the line to "SELV" circuits (typical for application interface).

NOTE 4 – The 20-mA current limit is not derived from any electrical safety specification. Its aim is to limit the power budget delivered by the network when wetting current is applied.

20) Modifications to clause D.3 – "Symbol rates"

Revise the text in clause D.3 as follows:

D.3 Symbol rates

For Annex A and Annex F operational modes, signal regenerators may transmit at symbol rates up to and including 280 ksymbol/s in two-wire mode, the optional four-wire mode, or the optional *M*-pair mode. This corresponds, for 16-TCPAM, to maximum user data rates (not including framing overhead) of 832 kbit/s per pair~~ and *M* × 832 kbit/s for two-wire and *M*-pair operation, respectively~~. For 32 TCPAM, this corresponds to maximum user data rates (not including framing overhead) of 1.112 Mbit/s per pair. Operation at higher symbol rates is for further study.

For Annex B and Annex G operational modes, signal regenerators may transmit at symbol rates up to and including 685.33 ksymbol/s in two-wire mode, the optional four-wire mode, or the optional *M*-pair mode. This corresponds, for 16-TCPAM, to maximum user data rates (not including framing overhead) of 2.048 Mbit/s per pair~~ and *M* × 2.048 Mbit/s for two-wire and *M*-pair operation, respectively~~. For 32 TCPAM, this corresponds to maximum user data rates (not including framing overhead) of 2.728 Mbit/s per pair. Operation at higher symbol rates is for further study.

In either case, each STU and SRU on a span shall select the same operational data rate.

21) Modification to clause D.4 – "PSD masks"

Revise the text in clause D.4 as follows:

D.4 PSD masks

Any of the PSDs from Annex A or Annex B (or the corresponding PSDs in Annex F or Annex G) may be used for the TR1 segment (STU-C to SRU_1-R), as appropriate to the given region. All other segments shall employ one of the appropriate symmetric PSDs, as described in either A.4.1 or B.4.1. The selection of PSD shall be limited by the symbol rate considerations of D.3.

22) Modifications to clauses E.8.7, E.8.8 and E.8.9

Revise and restructure the texts in clauses E.8.7, E.8.8 and E.8.9 as follows:

E.8.7 ~~Signalling~~ Messages over the SHDSL EOC or the fast signalling channel

The ISDN status signalling information can be optionally transmitted over two different channels:

- SHDSL EOC.
- Fast signalling channel.

In both cases, SHDSL EOC messages with their HDLC-like format are used to transport the ISDN message code. The STU-C as well as the STU-R unit can initiate EOC messages. Generally, the ISDN-related EOC messages are transported over the SHDSL EOC. In some applications, it is necessary to set up an additional fast signalling channel with 8 kbit/s bandwidth for these ISDN-related EOC messages. This is the case when more than four ISDN BRAs are used. It may also be used when low latency signalling is required or when another TPS-TC's signalling (e.g., ATM) has substantially restricted the use of the SHDSL EOC channel.

The following description relates to SHDSL core only and must be used in association with the appropriate ISDN BRA specifications for digital transmission system, user network interface layer 1 and access digital section.

E.8.7.1 SHDSL EOC messages

The EOC messages number 20 and 148 are used to transmit the ISDN maintenance and control functions as well as the other ISDN EOC messages.

Table E.12/G.991.2 – ISDN Request – Message ID 20

Octet #	Contents	Data Type	Reference
1	Message ID 20	Message ID	
2 bits 4-7	ISDN BRA Number	Unsigned char	
2 bits 0-3	Unused		Set to 0000_2
3	ISDN message code		

Table E.13/G.991.2 – ISDN Response – Message ID 148

Octet #	Contents	Data Type	Reference
1	Message ID 148	Message ID	
2 bits 4-7	ISDN BRA Number	Unsigned char	
2 bits 0-3	Unused		Set to 0000_2
3	ISDN message code		

ISDN BRA Number: Each ISDN BRA can be addressed independently. To each ISDN BRA a four-digit number is assigned in bits 4-7 of octet 2 in Message IDs 20 and 148 (BRA 1 = 0000, ..., BRA 6 = 0101).

E.8.7.2 ISDN message codes

The message codes which are contained as an octet in the SHDSL EOC message "ISDN Requests" are listed in Table E.14. The message codes which are contained as an octet in the SHDSL EOC message "ISDN Response" are listed in Table E.15.

Table E.14/G.991.2 – ISDN message codes commands

Function	Message	EOC message code	Comment
S-Bus Control	SIA	0001 0000	S-interface activated (STU-C → STU-R)
	SID	0001 0001	S-interface deactivated (STU-C → STU-R)
	SAI	0001 0010	S-interface ~~activated~~ activation initiated (STU-R → STU-C)
	SDI	0001 0011	S-interface ~~deactivated~~ defect indication (STU-R → STU-C)
ISDN Transceiver Status	ACT	0000 0001	Readiness for layer 2 communication (STU-C → STU-R) (STU-R → STU-C)
	DEA	0000 0010	Intention to deactivate (STU-C → STU-R)
	CSO	0000 0011	Cold start only (STU-R → STU-C)
BRA Termination Reset	S reset	0000 0000	Reset of ISDN control unit at STU-R (STU-C → STU-R)
ISDN EOC Messages	Operate 2B + D loopback	0011 0001	S-interface activate with loop 2 (STU-C → STU-R)
	Operate B1-channel loopback (Note)	0011 0010	Operate B1-channel loop can be requested whenever the SHDSL link is activated (STU-C → STU-R)
	Operate B2-channel loopback (Note)	0011 0011	Operate B2-channel loop can be requested whenever the SHDSL link is activated (STU-C → STU-R)
	Return to normal	0011 1111	(STU-C → STU-R)
	Hold state	0011 0000	(STU-C → STU-R)
NOTE – The use of B1- and B2-channel loopbacks is optional. However, the loopback codes are reserved for these functions.			

Table E.15/G.991.2 – ISDN message codes responses

Function	Message	EOC Message Code	Comment
S-Bus Control	SIA	1001 0000	S-interface activated
	SIAF	1101 0000	S-interface activation failed
	SID	1001 0001	S-interface deactivated
	SIDF	1101 0001	S-interface deactivation failed
	SAI	1001 0010	S-interface ~~activated~~ activation initiated
	SDI	1001 0011	S-interface ~~deactivated~~ defect indication
ISDN Transceiver Status	ACT	1000 0001	Readiness for layer 2 communication
	DEA	1000 0010	Intention to deactivate
	CSO	1000 0011	Cold start only
BRA Termination Reset	S reset ack	1000 0000	Reset of ISDN control unit at STU-R
ISDN EOC Messages	Operate 2B + D loopback (success)	1011 0001	S-interface activate with loop2
	Operate 2B + D loopback (failure)	1111 0001	
	Operate B1-channel loopback (success)	1011 0010	Operate B1-channel loop can be requested whenever the SHDSL link is activated
	Operate B1-channel loopback (failure)	1111 0010	
	Operate B2-channel loopback (success)	1011 0011	Operate B1-channel loop can be requested whenever the SHDSL link is activated
	Operate B2-channel loopback (failure)	1111 0011	
	Return to normal (success)	1011 1111	
	Return to normal (failure)	1111 1111	
	Hold state	1011 0000	
	Unable to comply acknowledgement	1111 0100	

E.8.7.3~~E.8.8~~ S-Bus control messages

The ISDN S-buses which connect the ISDN terminals with the STU-R can be controlled independently with the respective message codes (SIA, SID, SAI, SDI) for each S-bus. The STU-C side can activate and deactivate the S bus and gets status information. These messages are transmitted as SHDSL EOC messages. The STU-C can activate and deactivate the S-bus; the STU-R can only activate the S-bus and get status information.

The S-interfaces of each ISDN BRA can be addressed independently. To each ISDN BRA a four-digit number is (BRA 1 = 0000, ..., BRA 6 = 0101) contained in the ISDN-related SHDSL EOC messages.

SIA: In the STU-C to STU-R direction this function is used to request the STU-R to activate the interface at the S reference point. If the interface at the S reference point is to be activated this message may be sent. In the STU-R to STU-C direction the respective response is SIA (S-Interface Activated).

SID: In the STU-C to STU-R direction, this function is used to request the STU-R to deactivate the interface at the S reference point. If the interface at the S reference point is to be deactivated, this message may be sent to release a complete loopback in the STU-R. In the STU-R to STU-C direction the respective response is SID (S-Interface Deactivated).

SAI: In the STU-R to STU-C direction, this message is used to inform the STU-C that the S-interface and S-bus have been activated by a terminal equipment. In the STU-C to STU-R direction, the respective response is **SAI**.

SDI: In the STU-R to STU-C direction, this message is used to inform the STU-C that the STU-R has lost the connection to the TE on the S-bus ~~S-interface and S-bus have been deactivated~~. In the STU-C to STU-R direction, the respective response is **SDI**.

E.8.7.4 ISDN transceiver status messages

ACT (Readiness for layer 2 communication): This message is used in STU-C to STU-R and in STU-R to STU-C direction to communicate readiness for layer 2 communications.

In the STU-R to STU-C or STU-C to STU-R direction, the respective response is also ACT.

CSO (Cold start-only): This message is used in STU-R to STU-C direction to indicate the cold start-only mode.

In the STU-C to STU-R direction, the respective response is also CSO.

~~E.8.9~~E.8.7.5 BRA termination reset

The status and condition of each ISDN BRA and its S-interface at the STU-R side can be individually monitored from the STU-C side. If a failure or blocking at one ISDN BRA is detected this situation can be resolved by a reset. "BRA termination reset" puts the control unit of the S-interface to its default state (the deactivated state). Other BRAs or other services are not affected.

E.8.7.6 ISDN OAM messages

Operate 2B+D/B1/B2 loopback: These messages are used in STU-C to STU-R direction to request the STU-R to transparently loop back towards the network at the interface at the S reference point the user-data 2B + D, resp. the individual B1 or B2 channel only. The loopback of the individual B-channels is optional. All loopbacks are released by deactivation with a SID message.

In the STU-R to STU-C direction, **Operate 2B+D/B1/B2 loopback** are the respective responses.

Return to normal: This message is used in STU-C to STU-R direction to request the STU-R to release all outstanding eoc-controlled operations and to reset the eoc-processor to its initial state.

In the STU-R to STU-C direction, **Return to normal** is the respective response.

Hold state: This message is used in the STU-C to STU-R direction to request the STU-R to maintain the eoc-processor and any active eoc-controlled operation in its present state. In the direction STU-R to STU-C, the message can be used to indicate that an eoc-frame with improper address has been received.

Unable to comply acknowledgement: This message is used in the STU-R to STU-C direction to indicate that the STU-R has validated the receipt of an eoc message, but this message is not in its menu.

E.8.8 Activation/Deactivation sequence charts

The sequence charts for the activation and deactivation of the S-bus are shown in Figures E.9b to E.9e.

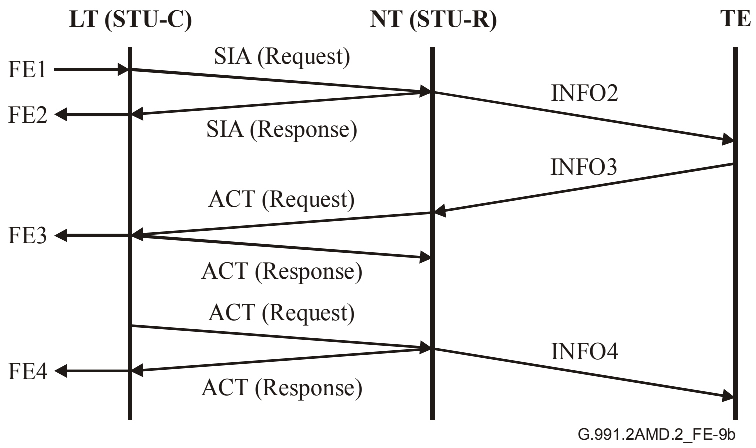

Figure E.9b/G.991.2 – ISDN BRA activation initiated by the exchange

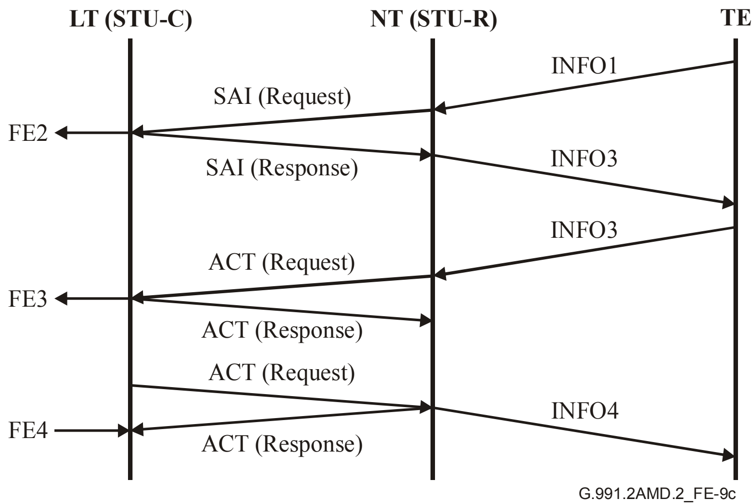

Figure E.9c/G.991.2 – ISDN BRA activation initiated by the terminal equipment

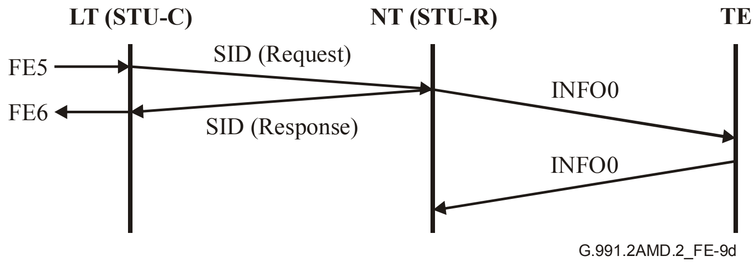

Figure E.9d/G.991.2 – ISDN BRA activation initiated by the terminal equipment

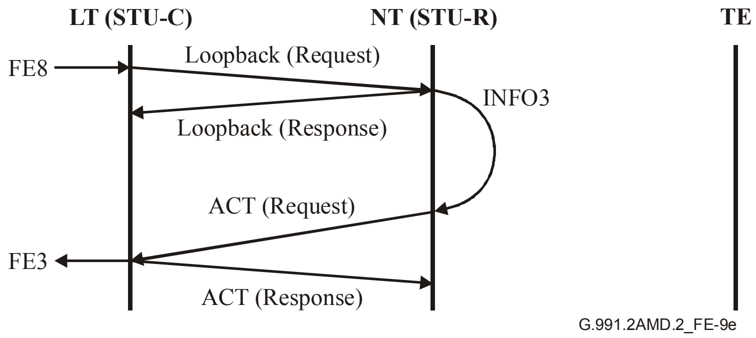

Figure E.9e/G.991.2 – ISDN BRA loopback 2 activation

E.8.9 State transition tables

In Tables E.16 and E.16a, examples for state transition tables of the STU-R and the STU-C are shown with the description of STU-C Failure Elements FE*x* in Table E.16b.

Table E.16/G.991.2 – State transition table for the NT

State number	NT1.1	NT1.2	NT1.3	NT1.4	NT1.5	NT1.5A	NT1.6	NT1.7	NT1.8	NT1.9	NT2.0	NT~~2.0A~~2.1	NT~~2.1~~2.2
State name	Reset	ISDN service deactivated	ISDN service activation				ISDN service activated				Loopback 2		
			Initiated	T-interface activated	T-interface activated ack	Active pending	Active	LOS/LFA at T pending	LOS/LFA at T	Deactivation initiated	Loopback pending	Loopback activated ack	Loopback operated
~~INFO~~Info sent (CP-~~IWF~~ INW→TE)	INFO0	INFO0	INFO0	INFO2	INFO2	INFO2	INFO4	INFO2	INFO2	INFO0	INFO2	INFO2	INFO4
Event \ Internal state	G1	G1	G1	G2	G2	G2	G3	G2	G2	G4	G4	G4	G4
Receiving INFO0	–	–	–	–	–	–	NT 1.7 SDI ~~(~~Request~~)~~	–	–	NT 1.2	–	–	–
Receiving INFO1	–	NT 1.3 SIA ~~SAI~~ ~~(~~Request~~)~~	–	–	–	–	–	–	–		–	–	–
Receiving INFO3 (or Loopback INFO2)	–	–	–	NT1.5 ACT ~~(~~Request~~)~~	–	–	–	–	NT1.5 ACT ~~(~~Request~~)~~	–	NT2.1 ACT ~~(~~Request~~)~~	–	–
LOS/LFA at T	–	–	–	–	–	–	NT 1.7 SDI (Request)	–	–	–	–	–	–
SIA ~~(~~Request~~)~~	–	NT1.4 SIA ~~(~~Response~~)~~	NT1.4 SIA Response	SIA Response	–	–	–	–	–	NT1.4 SIA ~~(~~Response~~)~~	–	–	–
SIA ~~(~~Response~~)~~	–	–	NT1.4		–	–	–	–	–	–	–	–	–
SID ~~(~~Request~~)~~	–	–	NT1.9 SID ~~(~~Response~~)~~	NT1.9 SID ~~(~~Response~~)~~	NT1.9 SID ~~(~~Response~~)~~	NT1.9 SID ~~(~~Response~~)~~	NT1.9 SID ~~(~~Response~~)~~	NT1.9 SID ~~(~~Response~~)~~	NT1.9 SID ~~(~~Response~~)~~	–	NT1.9 SID ~~(~~Response~~)~~	NT1.9 SID ~~(~~Response~~)~~	NT1.9 SID ~~(~~Response~~)~~
~~ACT~~Act ~~(Response)~~Request	–	–	–	–	NT1.5A	–	–	–	–	–	–	NT2.1	–
~~ACT~~Act ~~(~~Request~~)~~	–	–	–	–	–	NT1.6 ACT ~~(~~Response~~)~~	–	–	–	–	–	–	–
SID (Response)	–	–	–	–	–	–	–	–	–	NT1.2	–	–	–
ACT (Response)	–	–	–	–	NT1.6	NT1.6	–	–	–	–	–	–	–
Operate 2B+D loopback ~~(~~Request~~)~~	–	NT2.0 Operate 2B+D loopback ~~(success)~~ ~~(~~Response~~)~~	–NT2.0 Operate 2B+D loopback Response	–NT2.0 Operate 2B+D loopback Response	–NT2.0 Operate 2B+D loopback Response	–NT2.0 Operate 2B+D loopback Response	–	–NT2.0 Operate 2B+D loopback Response	–	–	–	–	–
S reset ~~(~~Request~~)~~	–	~~NT1.1~~S reset ~~ack~~ ~~(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack~~ ~~(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack~~ ~~(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack~~ ~~(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack~~ ~~(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack~~ ~~(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack~~ ~~(~~Response~~)~~	NT~~1.1~~1.2 S reset ~~ack~~ ~~(~~Response~~)~~
SDI ~~(~~Response~~)~~	–	–	–	–	–	–	–	NT1.8	–	–	–	–	–

Table E.16/G.991.2 – State transition table for the NT

State number	NT1.1	NT1.2	NT1.3	NT1.4	NT1.5	NT1.5A	NT1.6	NT1.7	NT1.8	NT1.9	NT2.0	NT~~2.0A~~2.1	NT~~2.1~~2.2
State name	Reset	ISDN service deactivated	ISDN service activation				ISDN service activated				Loopback 2		
			Initiated	T-interface activated	T-interface activated ack	Active pending	Active	LOS/LFA at T pending	LOS/LFA at T	Deactivation initiated	Loopback pending	Loopback activated ack	Loopback operated
SHDSL Data~~,~~ (c) failed~~,not reached~~	/	NT1.1	NT1.1	NT1.1	NT1.1	NT1.1	NT1.1	NT1.1	NT1.1	NT1.1	NT1.1	NT1.1	NT1.1
SHDSL Data~~,~~ (c) reached	NT1.2	–	–	–	–	–	–	–	–	–	–	–	–

Table E.16a/G.991.2 – State transition table for the LT

State number	LT1.1	LT1.2	LT1.3	LT1.4	LT1.5	LT1.6	LT1.7	LT1.8	LT2.0	LT2.1	LT2.2
State name	Reset	ISDN Service deactivated	ISDN service activation			ISDN service activated			Loopback 2		
			Initiated	T interface activated	Activate Pending	Active	LOS/LFA at T pending	Deactivation initiated	Loopback requested	Loopback pending	Loopback operated
FE sent (CO/IWF →ET) / Event	FE7	FE6	FE2	FE2	FE3	FE4	FE12	~~(Note)~~	FE3	FE3	FE4
FE1	–	LT1.3 SIA ~~(Request)~~	–	–	–	–	–	LT1.3 SIA ~~(Request)~~	–	–	–
FE5	–	–	Start T2 LT1.8 SID ~~(Request)~~	Start T2 LT1.8 SID ~~(Request)~~	Start T2 LT1.8 SID ~~(Request)~~	Start T2 LT1.8 SID ~~(Request)~~	Start T2 LT1.8 SID ~~(Request)~~	–	Start T2 LT1.8 SID ~~(Request)~~	Start T2 LT1.8 SID ~~(Request)~~	Start T2 LT1.8 SID ~~(Request)~~
FE8	–	LT2.0 Operate 2B+D loopback ~~(Request)~~	↓	↓	LT2.0 Operate 2B+D loopback ~~(Request)~~	LT2.0 Operate 2B+D loopback ~~(Request)~~	↓	↓	↓	↓	↓
~~S reset~~	~~LT1.1~~	~~LT1.1~~	~~LT1.1~~	~~LT1.1~~	~~LT1.1~~	~~LT1.1~~	~~LT1.1~~	~~LT1.1~~	~~LT1.1~~	~~LT1.1~~	~~LT1.1~~
SAI ~~(Request)~~	–	LT1.4 SAI ~~(Response)~~	LT~~1.3~~1.4 SAI ~~(Response)~~	–	–	–	–	–	–	–	–

Table E.16a/G.991.2 – State transition table for the LT

State number	LT1.1	LT1.2	LT1.3	LT1.4	LT1.5	LT1.6	LT1.7	LT1.8	LT2.0	LT2.1	LT2.2
State name	Reset	ISDN Service deactivated	ISDN service activation			ISDN service activated			Loopback 2		
			Initiated	T interface activated	Activate Pending	Active	LOS/LFA at T pending	Deactivation initiated	Loopback requested	Loopback pending	Loopback operated
ACTAct (Request)	–	–	–	LT1.5 ACT (Response) ACT (Request)	–	–	LT1.5 ACT (Response) ACT (Request)	–	–	LT2.2 ACT (Response)	–
SDI (Request)	–	–	–	–	–	LT1.7 SDI (Response)	–	–	–	–	–
SIA (Response)	–	–	LT1.4	–	–	–	–	–	–	–	–
SID Response	–	–	–	–	–	–	–	LT1.2	–	–	–
Act Response	–	–	–	–	LT1.6	–	–	–	–	–	–
Operate 2B+D loopback (success) (Response)	–	–	–	–	–	–	|	|	LT2.1	–	–
S reset ack (Response)	LT1.2	S reset Request	LT1.2 S reset Request	LT1.2 S reset Request	LT1.2 S reset Request	LT1.2 S reset Request	LT1.2 S reset Request	LT1.2 S reset Request	LT1.2 S reset Request	LT1.2 S reset Request	LT1.2 S reset Request
SHDSL Data (c) failed	/	LT1.1	LT1.1	LT1.1	LT1.1	LT1.1	LT1.1	LT1.1	LT1.1	LT1.1	LT1.1
SHDSL Data (c) reached	LT1.2	–	–	–	–	–	–	–	–	–	–
Expiry Timer 2	–	–	–	–	–	–	–	LT1.3	–	–	–

Table E.16b/G.991.2 – Legend for the state transition tables

Name	Description
–	No state change
/	Impossible by definition of peer-to-peer physical layer procedures or system internal reasons.
|	Impossible by definition of the physical layer service.
Start T2	Start Timer T2 A description of timer T2 can be found in Note 2 to Table 6/I.430. ~~"Timer 2 (T2) prevents unintentional reactivation. Its value is 25 ms <= value <= 100 ms. This implies that the TE has to recognize INFO 0 and to react on it within 25 ms. If the NT is able to unambiguously recognize INFO 1, then the value of timer 2 may be 0, and an MPH-DEACTIVATE REQUEST would cause a direct transition from state G2 or G3 to G1. It should be noted that the unambiguous detection of INFO 1 may not be possible in passive bus configurations, considering all possible implementations."~~
Note	The FE sent to the network is identical to the FE sent prior to the issue of FE5 from the network.
FE1	(LT ← ET) Activate access
FE2	(LT → ET) Access activation initiated
FE3	(LT → ET) Access digital section activated
FE4	(LT → ET) Access or loopback activated
FE5	(LT ← ET) Deactivate access
FE6	(LT → ET) Access deactivated
FE7	(LT → ET) LOS/LFA in DS or loss of power in NT1
FE8	(LT ← ET) Activate loopback 2
FE12	(LT → ET) LOS/LFA at T reference point

~~**Table E-17/G.991.2 – Reset Request**~~

~~Message~~	~~EOC message code~~	~~Comment~~
~~S reset~~	~~0000 0000~~	

~~**Table E-18/G.991.2 – Reset Response**~~

~~Message~~	~~EOC message code~~	~~Comment~~
~~S reset acknowledge~~	~~1000 0000~~	

23) Modifications to clause F.3

Add the following text to the end of clause F.3, Mapper, after Table F.2:

2-PAM constellation mapping for Activation and Warm-Start

In activation mode (see 7.2.1) and during warm-start (see H.2.1), 2-PAM signalling is used. In 6.2.4, the mapping of the 2-PAM levels is defined for the case of 16-TCPAM transmission in data mode.

Table F.3 shows 2-PAM bit-to-level mapping for 16- and 32-level transmission. According to 7.2.1, the modulation format in activation mode shall be 2-PAM.

For 2-PAM, the output bits from the scrambler s(m) shall be mapped to an output level y(m) as follows in Table F.2a:

Table F.2a/G.991.2 – Mapping of scrambler output bits to PAM levels

Data mode constellation	Scrambler output s(m)	Mapper output level y(m)	Data mode index
16-TCPAM	0	–9/16	0011
	1	+9/16	1000
32-TCPAM	0	–19/32	00110
	1	+19/32	10101

In the case of 16-TCPAM data mode transmission, the levels corresponding to the scrambler outputs 0 and 1 shall be identical to the levels in the 16-TCPAM constellation (see Table F.2a) corresponding to indexes 0011 and 1000, respectively.

In the case of 32-TCPAM data mode transmission, the levels corresponding to the scrambler outputs 0 and 1 shall be identical to the levels in the 32-TCPAM constellation (see Table F.2a) corresponding to indexes 00110 and 10101, respectively.

24) Text for new Annex G

Add the following text for new Annex G:

Annex G

Region 2 requirements for payload data rates up to 5696 kbit/s

G.1 Scope

The clauses in this annex provide the additions and modifications to the corresponding clauses in the main body and in Annex B for payload data rates between 192 and 5696 kbit/s. Support for this annex is optional.

NOTE – Some countries have standards for spectrum management requirements that limit the length of the lines for transmission of certain signal levels in this annex. For example, the ANFP applies in the UK access network or the PGS applies in the French access network.

G.2 Data rate

Table G.1 shows the relationship between the payload data rate and the symbol rate at 16- or 32-TCPAM encoding for the one-pair mode.

The operation of the TU in data mode at the specified information rate shall be as specified in Table G.1.

Table G.1/G.991.2 – Framed data mode rates

Payload data rate, R (kbit/s)	Modulation	Symbol rate (ksymbol/s)	K (Bits per symbol)
$R = n \times 64 + i \times 8$	16-TCPAM	$(R+8) \div 3$	3
$R = n \times 64 + i \times 8$	16-TCPAM	$(R+8) \div 4$	4

This annex extends the single-pair rates specified in the main body (per clause 5, reiterated in 7.1.1, 8.1 and 8.2). It is applicable for single-pair rates given by $n \times 64 + i \times 8$ kbit/s where for 16-TCPAM, $36 \le n \le 60$ and $0 \le i \le 7$. For 16-TCPAM and n = 36, the applicable values of i are $2 \le i \le 7$. For 16-TCPAM and $n = 60$, the applicable value of i are 0 or 1. This corresponds to (payload) data rates from 2320 kbit/s to 3848 kbit/s in increments of 8 kbit/s for 16-TCPAM. For 32-TCPAM, $12 \le n \le 89$ and $0 \le i \le 7$. For 32-TCPAM and $n = 89$, the applicable value of i is 0. This corresponds to (payload) data rates from 768 kbit/s to 5696 kbit/s in increments of 8 kbit/s for 32-TCPAM.

This annex is also applicable for optional operation on more than one pair (4-wire or *M*-pair mode).

G.2.1 Support for multiple encodings

Support for the data rates specified in this annex is optional, and, as such, a STU supporting this annex is not required to support all specified data rates. For each rate that an STU-R supports, it shall support all available encodings (i.e., both 16- and 32-TCPAM for rates where both encodings are specified). Support for multiple encodings is optional for the STU-C.

G.2.2 G.994.1 pre-activation sequence

As specified in 6.4, ITU-T Rec. G.994.1 is used to begin the pre-activation sequence.

To support a wide range of data rates and multiple encodings, this clause introduces a new way to encode data rates in G.994.1 code points. This method of encoding rates is used for both the PMMS rates and the training rates. Data rates are encoded as a set of ranges, where each range is expressed as a 3-tuple (minimum, maximum, step). The 3-tuple represents all rates of the form $(m + k \times s) \times$ (64 kbit/s) where m is the minimum value, s is the step value, and k is the set of all integers greater than or equal to zero such that $m + k \times s$ is less than or equal to the maximum value. Thus, for example, the 3-tuple (40, 70, 10) represents the rates 40 × 64 kbit/s, 50 × 64 kbit/s, 60 × 64 kbit/s, and 70 × 64 kbit/s.

Each data rate parameter in this annex can be expressed as a set of between 1 to 8 ranges, where the supported rates are the union of those supported by the individual ranges. Thus, for example, the 3-tuples (20,30,4), (40,70,10) represent the rates 20 × 64 kbit/s, 24 × 64 kbit/s, 28 × 64 kbit/s, 40 × 64 kbit/s, 50 × 64 kbit/s, 60 × 64 kbit/s, and 70 × 64 kbit/s. If all bits of the extended base data rate minimum and maximum are set to zero, then those rates are not supported for line probe. If only one range of rates is required, then only the octets associated with (min1,max1,step1) shall be sent.

Also, in many cases, the values in the data range 3-tuple can be less than or equal to 89 (representing the maximum payload data rate of 5696 kbit/s supported in this annex). When using G.994.1 code point representation, only 6 bits are available for the value of an NPAR(3). To support numbers greater than 63, the value must be split across multiple octets. When encoding a data range using G.994.1, 4 octets are used, where the first octet contains the highest order bit from each of the values in the 3-tuple. This is illustrated in Table 11.18.10/G.994.1.

The complete set of rate capabilities shall be the union of the extended rates specified in this annex with the non-extended rates specified in the main body.

Ranges of rates may overlap, and may contain some rates which are identical. For example, the 3-tuples (40,60,10) and (50,70,5) would be a valid set of ranges. In this case, the union of these two 3-tuples would be the rates 40 × 64 kbit/s, 50 × 64 kbit/s, 55 × 64 kbit/s, 60 × 64 kbit/s, 65 × 64 kbit/s, and 70 × 64 kbit/s. Note that, for PMMS, if two ranges contain some rates which are identical, the probe waveforms associated with these identical rates are only sent once.

The following definition is added to the G.994.1 code point definitions in 6.4.1 for the support of the extended data rates specified in this annex.

Extended base data rate

These octets are used to specify payload rates for this annex, as follows:

– The PMMS octets indicate rates for line probing segments. Note that while PMMS uses 2-PAM modulation, the PMMS symbol rates are specified assuming 32-TCPAM encoding, so the PMMS symbol rate (in ksymbol/s) would be equal to the (payload data rate (kbit/s) + 8 kbit/s)/4. Valid values for min and max shall be between 49 and 89, inclusive, and valid values for step shall be between 1 and 40, inclusive. The variables j5 and j6 associated with the PMMS rates shall be independent, and shall range from 1 to 8, inclusive. If only one range of rates is required, then only the octets associated with (min1,max1,step1) shall be sent.

– The training parameter octets indicate extended payload data rates supported.

– In CLR, upstream training parameters indicate which data mode rates the STU-R is capable of transmitting and downstream training parameters indicate which data mode rates the STU-C is capable of receiving. If the optional line probe is used, the receiver training parameters will be further limited by the probe results. Valid values for minimum and maximum shall be between 36 and 60, inclusive, for 16-TCPAM and between 12 and 89, inclusive, for 32-TCPAM. Valid values for step shall be between 1 and 89, inclusive. The variables j1, j2, j3 and j4 associated with the training rates shall be independent, and shall range from 1 to 8, inclusive. The STU-R shall indicate support for both 16- and 32-TCPAM for all supported rates for which both encodings are defined in Tables G.2 and G.3.

– In CL, downstream training parameters indicate which data mode rates the STU-C is capable of transmitting and upstream training parameters indicate which data mode rates the STU-C is capable of receiving. Valid values for minimum and maximum shall be between 36 and 60, inclusive, for 16-TCPAM and between 12 and 89, inclusive, for 32-TCPAM. Valid values for step shall be between 1 and 89, inclusive. The variables j1, j2, j3 and j4 associated with the training rates shall be independent, and shall range from 1 to 8, inclusive. If optional line probe is used, the receiver training parameters will be further limited by the probe results.

Data rate selections shall be specified in MP and MS messages by setting the maximum and minimum rates to the same value.

G.3 Mapper

The K + 1 bits $Y_K(m)$, …, $Y_1(m)$, and $Y_0(m)$ shall be mapped to a level x(m). In 6.1.2.3, the mapper function is specified for 16-TCPAM. This annex extends that mapping to include both 16- and 32-TCPAM encodings.

Table G.2 shows the bit-to-level mapping for 16- and 32-level mapping.

Table G.2/G.991.2 – Data mode bit-to-level mapping

$Y_4(m)$	$Y_3(m)$	$Y_2(m)$	$Y_1(m)$	$Y_0(m)$	32-PAM (5 bits)	16-PAM (4 bits)
0	0	0	0	0	–31/32	–15/16
0	0	0	0	1	–29/32	–13/16
0	0	0	1	0	–27/32	–11/16
0	0	0	1	1	–25/32	–9/16
0	0	1	0	0	–23/32	–7/16
0	0	1	0	1	–21/32	–5/16
0	0	1	1	0	–19/32	–3/16

Table G.2/G.991.2 – Data mode bit-to-level mapping

Y_4(m)	Y_3(m)	Y_2(m)	Y_1(m)	Y_0(m)	32-PAM (5 bits)	16-PAM (4 bits)
0	0	1	1	1	–17/32	–1/16
0	1	1	0	0	–15/32	1/16
0	1	1	0	1	–13/32	3/16
0	1	1	1	0	–11/32	5/16
0	1	1	1	1	–9/32	7/16
0	1	0	0	0	–7/32	9/16
0	1	0	0	1	–5/32	11/16
0	1	0	1	0	–3/32	13/16
0	1	0	1	1	–1/32	15/16
1	1	0	0	0	1/32	–
1	1	0	0	1	3/32	–
1	1	0	1	0	5/32	–
1	1	0	1	1	7/32	–
1	1	1	0	0	9/32	–
1	1	1	0	1	11/32	–
1	1	1	1	0	13/32	–
1	1	1	1	1	15/32	–
1	0	1	0	0	17/32	–
1	0	1	0	1	19/32	–
1	0	1	1	0	21/32	–
1	0	1	1	1	23/32	–
1	0	0	0	0	25/32	–
1	0	0	0	1	27/32	–
1	0	0	1	0	29/32	–
1	0	0	1	1	31/32	–

2-PAM constellation mapping for Activation and Warm-Start

In activation mode (see 7.2.1) and during warm-start (see H.2.1), 2-PAM signalling is used. In 6.2.4, the mapping of the 2-PAM levels is defined for the case of 16-TCPAM transmission in data mode.

Table G.3 shows 2-PAM bit-to-level mapping for 16- and 32-level transmissions. According to 7.2.1, the modulation format in activation mode shall be 2-PAM.

For 2-PAM, the output bits from the scrambler s(m) shall be mapped to an output level y(m) as follows:

Table G.3/G.991.2 – Mapping of scrambler output bits to PAM levels

Data mode constellation	Scrambler output s(m)	Mapper output level y(m)	Data mode index
16-TCPAM	0	–9/16	0011
	1	+9/16	1000
32-TCPAM	0	–19/32	00110
	1	+19/32	10101

In the case of 16-TCPAM data mode transmission, the levels corresponding to the scrambler outputs 0 and 1 shall be identical to the levels in the 16-TCPAM constellation (Table G.3) corresponding to indexes 0011 and 1000, respectively.

In the case of 32-TCPAM data mode transmission, the levels corresponding to the scrambler outputs 0 and 1 shall be identical to the levels in the 32-TCPAM constellation (Table G.3) corresponding to indexes 00110 and 10101, respectively.

G.4 PSD masks

For symmetric PSDs using 16-TCPAM payload data rates greater than or equal to 2320 kbit/s, and for symmetric PSDs using 32-TCPAM payload data rates greater than or equal to 768 kbit/s, the measured transmit PSD of each STU shall not exceed the PSD masks specified in this clause ($PSDMASK_{SHDSL}(f)$), and the measured total power into 135 Ω shall fall within the range specified in this clause ($P_{SHDSL} \pm 0.5$ dB).

The inband PSD for $0 < f < 2.0$ MHz shall be measured with a 10-kHz resolution bandwidth.

NOTE 1 – Large PSD variations over narrow frequency intervals (for example, near the junction of the main lobe with the noise floor) might require a smaller resolution bandwidth (RBW) to be used. An appropriate way would be to choose RBW such that there is no more than 1-dB change in the signal PSD across the RBW.

For all values of framed data rate available in the STU-C or STU-R, the following set of PSD masks ($PSDMASK_{\mathrm{SHDSL}}(f)$) shall be selectable:

$PSDMASK_{\mathrm{SHDSL}}(f) =$

$$\begin{cases} P_1(f) = 10^{\frac{-PBO}{10}} \times \frac{K_{SDSL}}{R_s} \times \frac{1}{f_{sym}} \times \frac{\left[\sin\left(\frac{\pi f}{f_{sym}}\right)\right]^2}{\left(\frac{\pi f}{f_{sym}}\right)^2} \times \frac{1}{1+\left(\frac{f}{f_{3\,\mathrm{dB}}}\right)^{2\times Order}} \times 10^{\frac{MaskOffsetlB(f)}{10}} \ \text{[W/Hz]} & f < f_{\mathrm{int}} \\ P_2(f) = -90 \text{ dBm/Hz peak with maximum power in a } [f, f+1 \text{ MHz}] \text{ window of} & f_{\mathrm{int}} \le f \le 3.184 \text{ MHz} \\ \qquad [10 * \log_{10}(0.5683 \times 10^{-4} \times f^{-1.5}) + 90] \text{ dBm} & \\ P_3(f) = -90 \text{ dBm/Hz peak with maximum power in a } [f, f+1 \text{ MHz}] \text{ window of } -50 \text{ dBm} & 3.184 \text{ MHz} < f \le f_{\max} \end{cases}$$

where:

PBO = the Power Backoff value in dB, as defined in G.5

K_{SHDSL}, f_{sym}, f_{3dB} and Order are defined in Table G.4 (parts 1 and 2)

f = frequency in Hz

R_s = 135 Ω

$$\mathrm{MaskOffsetdB}(f) = \begin{cases} 1 + 0.4 \times \frac{f_{\mathrm{3dB}} - f}{f_{\mathrm{3dB}}} & \text{[dB]}, \quad f < f_{\mathrm{3dB}} \\ 1 & \text{[dB]}, \quad f \ge f_{\mathrm{3dB}} \end{cases}$$

f_{int} = lowest frequency above f_{3dB} where the expressions for $P_1(f)$ and $P_2(f)$ intersect

$f_{\max}$ = 11.040 MHz

Table G.4/G.991.2 (Part 1) – Symmetric PSD parameters, 16-TCPAM

Payload data rate, R (kbit/s)	K_{SHDSL} (V^2)	Order	f_{sym} (Hz)	f_{3dB} (Hz)	P_{SHDSL} (dBm)
$2320 \le R \le 3848$	9.9	6	$(R+8)/3$	$1.0 \times f_{\mathrm{sym}}/2$	14.5

Table G.4/G.991.2 (Part 2) – Symmetric PSD parameters, 32-TCPAM

Payload data rate, R (kbit/s)	K_{SHDSL} (V^2)	Order	f_{sym} (Hz)	f_{3dB} (Hz)	P_{SHDSL} (dBm)
$768 \le R < 2688$	7.86	6	$(R+8)/4$	$1.0 \times f_{\mathrm{sym}}/2$	13.5
$2688 \le R \le 5696$	9.9	6	$(R+8)/4$	$1.0 \times f_{\mathrm{sym}}/2$	14.5

For 0-dB power backoff, the measured transmit power into 135 Ω shall fall within the range $P_{\mathrm{SHDSL}} \pm 0.5$ dB. For power backoff values other than 0 dB, the measured transmit power into 135 Ω shall fall within the range $P_{\mathrm{SHDSL}} \pm 0.5$ dB minus the power backoff value in dB. The measured transmit PSD into 135 Ω shall remain below $PSDMASK_{\mathrm{SHDSL}}(f)$. Figure G.1 shows the PSD masks with 0 dB power backoff for payload data rates of 3848 kbit/s (16-TCPAM) and 5696 kbit/s (32-TCPAM).

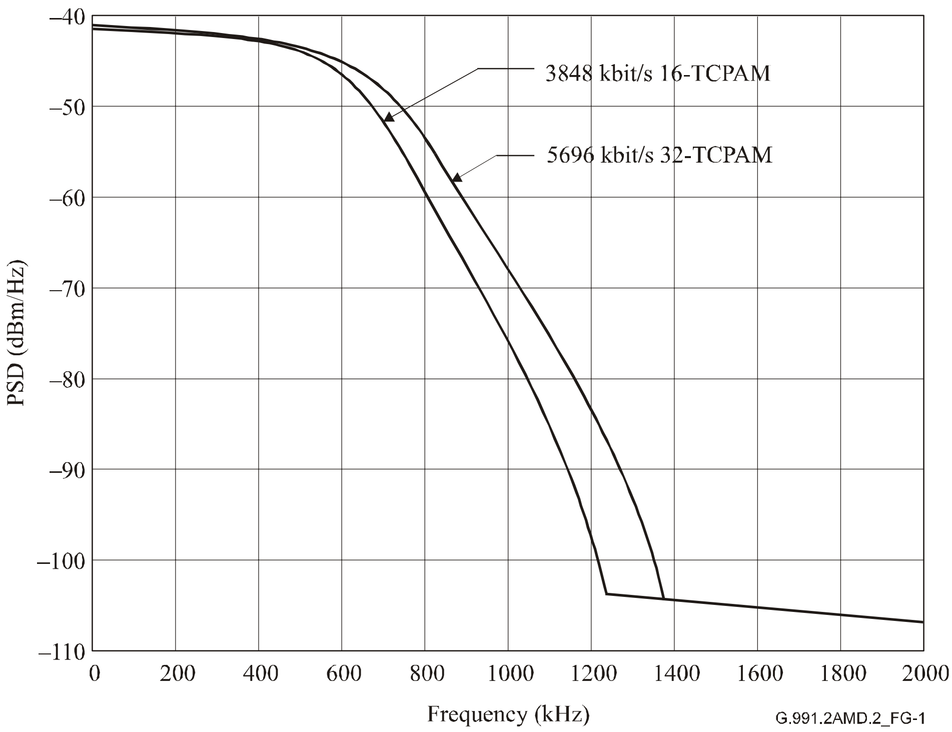

Figure G.1/G.991.2 – PSD masks for 0-dB power backoff

The equation for the nominal PSD measured at the terminals is:

$NominalPSD_{\mathrm{SDSL}}(f) =$

$$
\begin{cases}
P_i(f) = 10^{\frac{-PBO}{10}} \times \dfrac{K_{SHDSL}}{R_s} \times \dfrac{1}{f_{sym}} \times \dfrac{\left[\sin\left(\dfrac{\pi f}{f_{sym}}\right)\right]^2}{\left(\dfrac{\pi f}{f_{sym}}\right)^2} \times \dfrac{1}{1+\left(\dfrac{f}{f_{3\mathrm{dB}}}\right)^{2\times Order}} \times \dfrac{f^2}{f^2+f_c^2} [\mathrm{W/Hz}] & f < f_{\mathrm{int}} \\
P_2(f) = 0.5683 \times 10^{-4} \times f^{-1.5} \ [\mathrm{W/Hz}] & f_{\mathrm{int}} \le f \le 3.184 \text{ MHz} \\
P_3(f) + -110 \text{ dBm/Hz} & 3.184 \text{ MHz} < f \le f_{\max}
\end{cases}
$$

where:

PBO = the Power Backoff value in dB, as defined in G.5

K_{SHDSL}, f_{sym}, f_{3dB} and Order are defined in Table G.4 (parts 1 and 2)

f = frequency in Hz

f_c = is the transformer cut-off frequency, assumed to be 5 kHz

R_s = 135 Ω

f_{int} = lowest frequency above f_{3dB} where the expressions for $P_1(f)$ and $P_2(f)$ intersect

$f_{\max}$ = 11.040 MHz

Figure G.2 shows the nominal transmit PSDs with 14.5-dBm power for payload data rates of 3848 kbit/s (16-TCPAM) and 5696 kbit/s (32-TCPAM) kbit/s.

NOTE 2 – The nominal PSD is intended to be informative in nature; however, it is used for purposes of crosstalk calculations as representative of typical implementations.

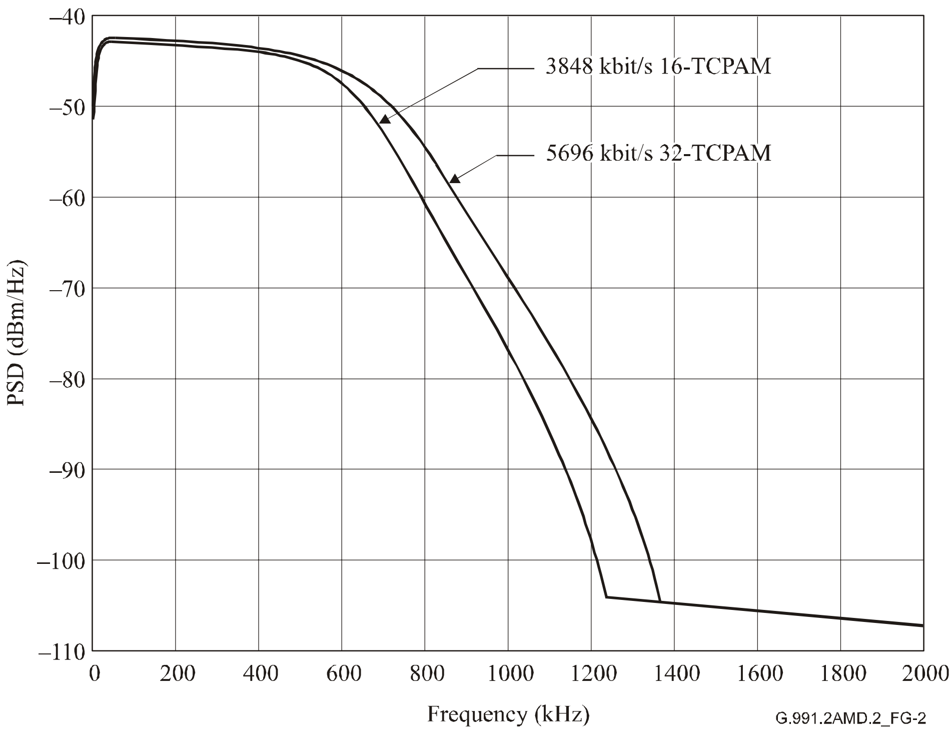

Figure G.2/G.991.2 – Nominal PSDs for 0-dB power backoff

G.5 Power backoff

In order to reduce crosstalk to other xDSL transmission systems, modified power backoff shall be implemented at SHDSL symbol rates greater than 770.67 ksymbols/s. The STU-C selects the power backoff value that shall be applied on STU-C and STU-R side and transmits this values in the appropriate octets of the final Mode Select message in the PACC to the STU-R. The STU-R shall apply the power backoff value contained in the final Mode Select message received from the STU-C.

PBO can be defined as a function of the measured EPL or SNR.

The definition of the EPL is identical to that in 6.1.5. The assignment of power backoff values in 4-wire/M-pair mode shall be as specified in 6.1.5.

If no network-specific PBO has been communicated, the default power backoff shall be applied. The PBO shall not exceed the maximum power backoff value.

Table G.5/G.991.2 – Default power backoff values

Estimated power loss/dB	Maximum power backoff/dB	Default power backoff/dB for 16-TCPAM	Default power backoff/dB for 32-TCPAM
EPL > 10	–31	0	0
10 ≥ EPL > 9	–31	1	0
9 ≥ EPL > 8	–31	2	0
8 ≥ EPL > 7	–31	3	1
7 ≥ EPL > 6	–31	4	2
6 ≥ EPL > 5	–31	5	3
5 ≥ EPL > 4	–31	6	4
4 ≥ EPL > 3	–31	7	5
3 ≥ EPL > 2	–31	8	6
2 ≥ EPL > 1	–31	9	7
1 ≥ EPL > 0	–31	10	8

NOTE – The default power backoff algorithm was designed for networks operating under noise B, C or D conditions. For networks operating under noise A conditions, the default power backoff value be the greater of 0 dB or the value of Table G.5 reduced by 4 dB for 16-TCPAM and 6 dB for 32-TCPAM.

G.6 Functional characteristics

Functional characteristics such as return loss, span powering, longitudinal balance, and longitudinal output voltage shall be as described in B.5.

G.7 Test loop length

The length of each testloop for Enhanced SHDSL transmission systems is specified in Tables G.6 and G.7. The specified insertion loss Y for each test loop at the specified test frequency measured with a 135-Ω termination (electrical length) is mandatory. If implementation tolerances of one testloop result in its electrical length being out of specification, then its total physical length shall be scaled accordingly to adjust this error.

The test frequency f_T is chosen to be a typical mid-band frequency in the spectrum of the e-SHDSL systems. The length is chosen to be a typical maximum value that can be supported correctly by the e-SHDSL transceiver under test. This value is bitrate-dependent: the higher the payload bit rate, the lower is the insertion loss that can be supported in practice.

Table G.6/G.991.2 – Values of the electrical length Y of the SHDSL noise testloops, when testing enhanced SHDSL at noise model A

Payload bitrate [kbit/s] (TCPAM constellation)		f_T [kHz]	L1 [m]	Y2 [dB] @f_T, @135 Ω	L2 [m]	Y3 [dB] @f_T, @135 Ω	L3 [m]	Y4 [dB] @f_T, @135 Ω	L4 [m]
3072 (coded 16)		250	< 3	12.3	1027	12.1	1303	11.3	1230
3848 (coded 16)		300	< 3	9.9	773	9.8	964	9.2	919
768 (coded 32)		100	< 3	24.6	2554	24.3	3493	24.1	3470
1024 (coded 32)		100	< 3	20.4	2121	20.1	2893	19.7	2831
2048 (coded 32)		150	< 3	12.3	1189	12.1	1561	11.3	1443
3072 (coded 32)		150	< 3	8.4	812	8.2	1029	7.2	918
3848 (coded 32)		200	< 3	6.4	579	6.4	715	5.3	605
4096 (coded 32)		250	< 3	6.2	521	6.3	638	5	535
5120 (coded 32)		300	< 3	4.3	340	4.3	403	3.6	336
5696 (coded 32)		350	< 3	3.6	270	3.6	314	3.1	266
Payload bitrate [kbit/s] (TCPAM constellation)		**f_T [kHz]**		**Y5 [dB] @f_T, @135 Ω**	**L5 [m]**	**Y6 [dB] @f_T, @135 Ω**	**L6 [m]**	**Y7 [dB] @f_T, @135 Ω**	**L7 [m]**
3072 (coded 16)		250		13.1	1755	14.1	440	11.7	800
3848 (coded 16)		300		11.4	1107	12.6	249	10.1	484
768 (coded 32)		100		25.4	7470	27.6	1655	25.2	2886
1024 (coded 32)		100		20.6	5910	23.7	1222	20.9	2314
2048 (coded 32)		150		12	2465	10.8	510	12.2	1106
3072 (coded 32)		150		7.6	1216	7.6	213	7.8	624
3848 (coded 32)		200		7.5	605	–	N/A	5.9	389
4096 (coded 32)		250		8.2	478	–	N/A	–	N/A
5120 (coded 32)		300		–	N/A	–	N/A	–	N/A
5696 (coded 32)		350		–	N/A	–	N/A	–	N/A
NOTE – The electrical length Y (insertion loss at specified frequency f_T) is mandatory, the (estimated) physical lengths L1-L7 are informative.									

Table G.7/G.991.2 – Values of the electrical length Y of the SHDSL noise testloops, when testing Enhanced SHDSL at noise model B, C or D

Payload bitrate [kbit/s] (TCPAM constellation)		**f_T [kHz]**	**L1 [m]**	**Y2 [dB] @f_T, @135 Ω**	**L2 [m]**	**Y3 [dB] @f_T, @135 Ω**	**L3 [m]**	**Y4 [dB] @f_T, @135 Ω**	**L4 [m]**
3072 (coded 16)		250	< 3	18.7	1561	18.8	2006	17.8	1916
3848 (coded 16)		300	< 3	16.5	1286	16.5	1630	15.8	1573
768 (coded 32)		100	< 3	31	3209	30.7	4407	30.2	4322
1024 (coded 32)		100	< 3	26.5	2751	26.3	3772	25.9	3715
2048 (coded 32)		150	< 3	18.8	1810	18.6	2412	18	2342
3072 (coded 32)		150	< 3	14.4	1390	14	1801	13	1684
3848 (coded 32)		200	< 3	12.4	1112	12.2	1416	11	1297
4096 (coded 32)		250	< 3	12.5	1039	12.2	1317	11.1	1206
5120 (coded 32)		300	< 3	10.3	808	10.2	1008	9.3	933
5696 (coded 32)		350	< 3	9.7	713	9.6	883	8.7	817
Payload bitrate [kbit/s] TCPAM constellation		**f_T [kHz]**		**Y5 [dB] @f_T, @135 Ω**	**L5 [m]**	**Y6 [dB] @f_T, @135 Ω**	**L6 [m]**	**Y7 [dB] @f_T, @135 Ω**	**L7 [m]**
3072 (coded 16)		250		19.2	3203	20.6	972	18.4	1442
3848 (coded 16)		300		17.3	2441	18.7	748	16.8	1072
768 (coded 32)		100		32	9630	33.2	2312	31.6	3711
1024 (coded 32)		100		26.9	7960	29.2	1849	27	3115
2048 (coded 32)		150		18.9	4354	17	1114	18.9	1890
3072 (coded 32)		150		13.5	2807	13.4	742	14.1	1297
3848 (coded 32)		200		12.1	1976	10.3	507	11.3	914
4096 (coded 32)		250		13.1	1776	14.3	451	11.9	814
5120 (coded 32)		300		11.3	1186	13.2	281	11.3	534
5696 (coded 32)		350		11.2	953	7.9	182	9.7	419
NOTE – The electrical length Y (insertion loss at specified frequency f_T) is mandatory, the (estimated) physical lengths L1-L7 are informative.									

NOTE – Some test performance reach numbers are currently not available (N/A) because the distances are small (fixed cable segments of 200 m in loop #5 and 350 m in loop #7) and more investigation on the implementation loss of the modem and the noise seen by the modem is required.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
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