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Technical Specification

Transmission and Multiplexing (TM); Access transmission system on metallic access cables; Symmetrical single pair high bitrate Digital Subscriber Line (SDSL); Part 1: Functional requirements

Reference

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Transmission and Multiplexing (TM).

The present document is part 1 of a multi-part TS covering the Transmission and Multiplexing (TM); Access transmission system on metallic access cables; Symmetrical single pair high bitrate Digital Subscriber Line (SDSL), as identified below:

Part 1: "Functional requirements";

Part 2: "Transceiver requirements".

The present document includes clarification of the noise models, power spectral density masks and evaluation data rates.

1 Scope

The present document specifies requirements for transceivers providing bidirectional symmetrical high bit rate transmission on a single metallic wire pair using the echo cancellation method. The technology is referred to as Symmetrical single-pair high bit rate Digital Subscriber Line (SDSL), and is applicable to metallic access transmission systems designed to provide digital access over existing, unshielded wire pairs.

NOTE: The system may also be used for asymmetrical transmission. Details for this application are for further study.

The present document is part 1 of the Technical Specification for SDSL and defines the functional requirements for SDSL. It is line code independent and is intended to set the boundary requirements and applications which SDSL systems are required to meet.

The requirements addressed in part 1 imply interoperability of SDSL systems. Such interoperability will be achieved when SDSL transceivers provided by different manufacturers are used in one SDSL link.

Part 2 defines implementation requirements which enable the functional requirements of part 1 to be met.

The definition of physical interfaces is outside the scope of the present document. The SDSL transmission system consists of an application independent core and an application specific block. The core is considered a transport bit-pump which transports information from one end of the metallic link to the other. The data is mapped into a frame which is considered to be the interface between the application specific and independent parts of the SDSL system, but this frame is only used internally and is not accessible.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] ETSI TS 101 272: "Transmission and Multiplexing (TM); Optical Access Networks (OANs) for evolving services; ATM Passive Optical Networks (PONs) and the transport of ATM over digital subscriber lines".

[2] ETSI TS 101 135 (V1.5): "Transmission and Multiplexing (TM); High bit-rate Digital Subscriber Line (HDSL) transmission systems on metallic local lines; HDSL core specification and applications for combined ISDN-BA and 2 048 kbit/s transmission".

[3] ETSI TS 102 080 (V1.3): "Transmission and Multiplexing (TM); Integrated Services Digital Network (ISDN) basic rate access; Digital transmission system on metallic local lines".

[4] ETSI ETS 300 001 (1997): "Attachments to the Public Switched Telephone Network (PSTN); General technical requirements for equipment connected to an analogue subscriber interface in the PSTN".

[5] EN 60950 (1992): "Safety of information technology equipment".

[6] ETSI ETS 300 019 (1992): "Equipment Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment".

[7] ETSI EN 300 386: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Telecommunication network equipment; ElectroMagnetic Compatibility (EMC) requirements".

[8] ITU-T Recommendation G.997.1 (1999): "Physical Layer Management for Digital Subscriber Line (DSL) Transceivers".

[9] CCITT Recommendation K.17 (1988): "Tests on power-fed repeaters using solid-state devices in order to check the arrangements for protection from external interference".

[10] ITU-T Recommendation K.20 (1991): "Resistibility of telecommunication switching equipment to overvoltages and overcurrents".

[11] ITU-T Recommendation K.21 (1996): "Resistibility of subscriber's terminal to overvoltages and overcurrents".

[12] ITU-T Recommendation O.9 (1999): "Measuring arrangements to assess the degree of unbalance about earth".

[13] TBR 21: "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".

[14] IETF RFC 1662: "PPP in HDLC-like Framing".

[15] ANSI X3.4 (R1997) (1986): "Information Systems - Coded Character Sets - 7-Bit American National Standard Code for Information Interchange (7-Bit ASCII)".

[16] ETSI ETS 300 012-1: "Integrated Services Digital Network (ISDN); Basic User-Network Interface (UNI); Part 1: Layer 1 specification".

[17] Council Directive 89/336/EEC of 3 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility.

3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

2B1Q	two binary one quaternary line code
BB	BroadBand
BER	Bit Error Rate
BERTS	Bit Error Rate Test Set
BT	Bridged Tap, an unterminated twisted pair section bridged across the line
CRC	Cyclic Redundancy Check
DLL	Digital Local Line
EMC	Electromagnetic Computability
eoc	Embedded Operations Channel
ETR	ETSI Technical Report
ETS	European Telecommunication Standard
FCS	Frame Check Sequence
FEXT	Far End Crosstalk
HDLC	High level Data Link Control
HDSL	High bit rate Digital Subscriber Line
ISDN BA	Integrated Services Digital Network Basic Rate Access
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector (former CCITT)
IUT	Item Under Test
LCL	Longitudinal Conversion Loss
lsb	least significant bit
LTU	Line Termination Unit
msb	most significant bit

NB	Narrow Band
NEXT	Near End Crosstalk
NTU	Network Termination Unit
O&M	Operation and Maintenance
OH	Overhead
PMS	Physical Medium Specific
POTS	Plain Old Telephone Service
PRBS	Pseudo-random bit sequence
PSD	Power Spectral Density
PSL	Power Sum Loss
REG	Regenerator
REG-C	NTU side of the regenerator
REG-R	LTU side of the regenerator
RF	Radio Frequency
rms	root mean square
SDH	Synchronous Digital Hierarchy
SDSL	Symmetric single pair high bit rate Digital Subscriber Line
SNI	Secure Network Interface
SNR	Signal to Noise Ratio
TC	Transmission Convergence
TMN	Telecommunication Management Network
TPS	Transmission Protocol Specific
TS	Technical Specification
TU-12	Tributary Unit-12
UTC	Unable to comply
VC-12	Virtual Container-12

4 Reference configuration

Figure 4.1 shows the reference configuration of an SDSL transmission system.

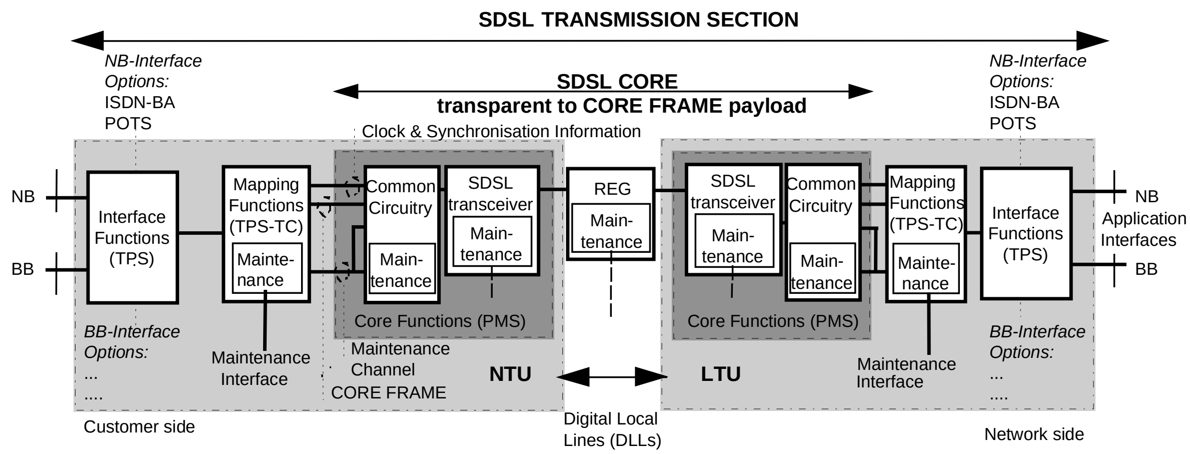


Figure 4.1: Reference configuration

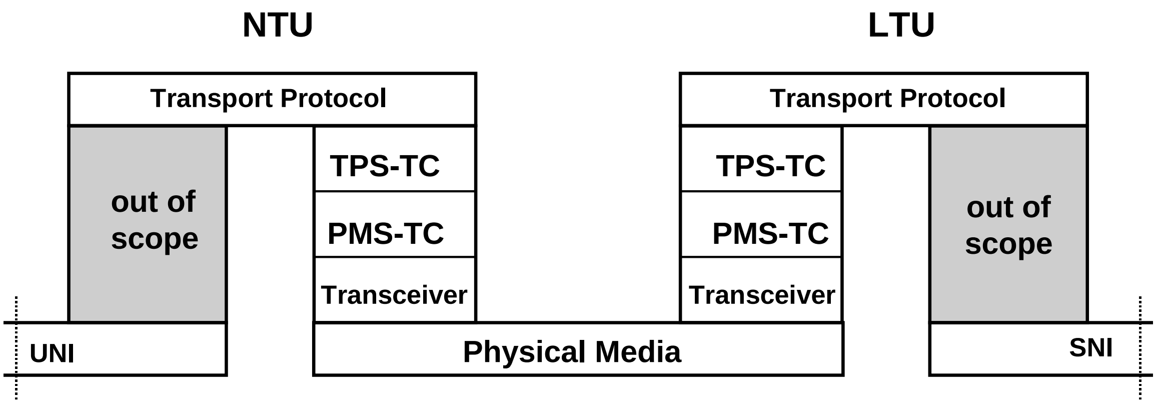


Figure 4.2: Protocol reference model

The reference configuration provides a bi-directional symmetrical channel with a variable bit rate that is under the control of the network management system of the operator. The maximum aggregate line bit rate is 2 320 kbit/s (allowing the support of TU-12 transport). An option is provided for transporting an independent narrowband channel. The narrowband channel shall be able to carry an ISDN-BA whose clock domain is not necessarily the same as that of the rest of the channel. The narrowband channel shall alternatively be capable of supporting analogue telephone channels. Remote power feeding shall be provided by the central office. A reduced power mode (for lifeline service in case of local power failure) shall be provided for one ISDN-BA or one analogue telephone connection.

The multiplexing of additional narrowband channels into the data channel is not precluded but is outside the scope of the present document. Lifeline service is not required for these channels.

The SDSL transmission system consists of the following functional blocks:

- interface;
- mapping;
- common circuitry;
- SDSL transceiver;
- optional regenerators.

The functions at the central office side constitute the Line Termination Unit (LTU) and act as master to the customer side functions, which constitute the Network Termination Unit (NTU), and to a regenerator where applicable.

The common circuitry providing for Physical Media Specific Transmission Convergence (PMS-TC) Layer and the SDSL transceivers comprise the core functions of the NTU and the LTU which, along with the Digital Local Line (DLL), make up the SDSL core. The DLL is commonly a copper twisted pair and may contain regenerators if an enhanced transmission range is required. A regenerator may be inserted at any convenient intermediate point in the SDSL core with appropriate insertion loss consideration. Power feeding and lifeline service may restrict the maximum achievable loop reach.

The SDSL core is application independent. It transparently transports the SDSL frames that it receives at its internal interfaces. The core functions are physical medium specific (PMS) and include:

- SDSL timing generation and recovery;
- start-up;
- scrambling and descrambling;
- coding and decoding;
- modulation and demodulation;
- echo cancellation;
- line equalization.

The mapping functions and the interface functions are application dependent and transmission protocol specific (TPS). The mapping function handles the Transmission Convergence (TC) Layer of the specific application including the maintenance and the mapping of the application frames into the SDSL frame. The TC-functions contain:

- channel multiplexing and demultiplexing;
- framing;
- frame synchronization;
- error detection;
- justification;
- maintenance.

The interface functional block provides interfaces to the data channel and the optional narrowband subchannel. The physical characteristics of the interfaces are application dependent. Implementation details are defined in the application descriptions.

The interfaces between the functional blocks are only logical separations and are not required to be physically accessible.

A clear embedded operations channel (eoc) is provided for within the system frame structure. The SDSL core is specified so as to promote interoperability of equipment from different vendors.

NOTE: The PMS-TC and TPS-TC layers are specified in detail in TS 101 272 [1].

5 Functions

5.1 SDSL Core Functions

The functions listed below are necessary for the correct operation of the SDSL core.

Table 5.1: Functions Related to the SDSL core

Functions related to the SDSL core	**LTU** <----> **NTU/ REG**
Transparent transport of SDSL frames	<---->
Stuffing and destuffing	<---->
Transmission error detection	<---->
Error reporting	<---->
Failure detection	<---->
Failure reporting	<---->
Bit timing	<---->
Frame alignment	<---->
Power back off	←-→
Transceiver start-up control	----->
Loopback control and co-ordination	<---->
Synchronization of SDSL transceivers	----->
Remote power feeding	----->
Wetting current (optional)	----->

5.1.1 Transparent transport of SDSL frames

This function provides the bidirectional transmission of the SDSL frames.

5.2 Stuffing and destuffing

This function, when used, provides for the synchronization of the application data clock to the SDSL transceiver system clock, by means of adding zero or four stuffing bits per SDSL frame.

5.3 Transmission error detection

This function provides for error performance monitoring of the SDSL transceiver systems in each SDSL frame.

5.4 Error reporting

This function provides for the reporting of errors detected.

5.5 Failure detection

This function provides for the detection of failures in the SDSL transceiver system.

5.6 Failure reporting

This function provides for the reporting of failures detected in the SDSL transceiver systems.

5.7 Bit timing

This function provides bit timing to enable the SDSL transceiver systems to recover information from the aggregate bit stream.

5.8 Frame alignment

This function provides information to enable the SDSL transceiver systems to recover the SDSL frame.

5.9 Power back-off

The transmitter shall have the ability to reduce its transmitted power in order to prevent crosstalk with transmission systems operating in the same multi pair cable. The power back off function shall be provided in both directions of transmission. The reduction of power shall be controlled by the network management depending on the SNR measured during the start-up procedure.

5.10 Transceiver start-up control

This function provides for the activation to reach the operational state. It may contain a preactivation procedure.

5.11 Loopback control and co-ordination

This function provides for the activation and deactivation of loopbacks in the LTU, the REG and the NTU.

5.12 Synchronization of SDSL transceivers

This function provides for the synchronization of the SDSL transceiver systems.

5.13 Remote power feeding

This function provides for remote power feeding of the NTU and/or the regenerators from the LTU.

5.14 Wetting current

This optional function provides for feeding of a low current on the pair to mitigate the effect of corrosion of contacts.

6 Transmission medium

6.1 Description

The transmission medium over which the digital transmission system is expected to operate is the local line distribution network, known as the digital local line (DLL). A digital local line distribution network employs cables of pairs to provide services to customers. In a local line distribution network, customers are connected to the local exchange via local lines. To simplify the provision of SDSL, a digital transmission system should be capable of satisfactory operation over the majority of metallic local lines without requirement of any special conditioning. In order to permit the use of SDSL transmission systems on the maximum possible number of digital local lines, the restrictions imposed by SDSL requirements are kept to the minimum necessary to guarantee acceptable operation.

6.2 Physical characteristics of a digital local line (DLL)

A digital local line (DLL) is constructed of one or more cable sections that are spliced or interconnected together.

The distribution or main cable is structured as follows:

- cascade of cable sections of different diameters and lengths;
- up to two bridged taps (BTs) may exist at various points in installation and distribution cables.

A general description of the DLL physical model is shown in figure 6.1 and typical examples of cable characteristics are given in table 6.1.

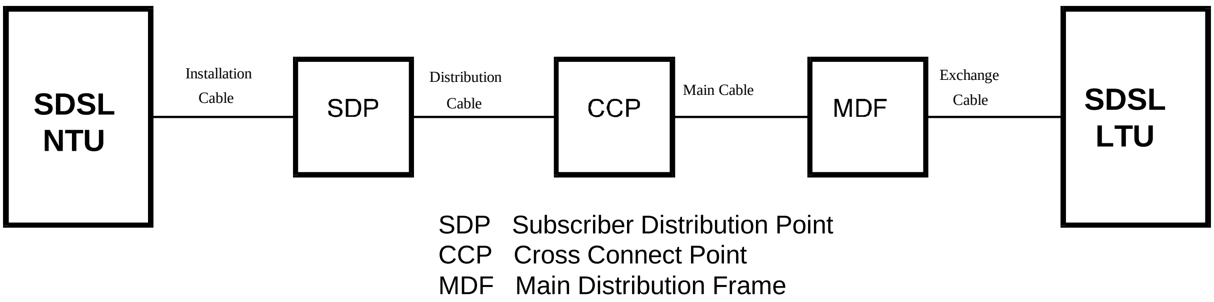


Figure 6.1: DLL physical model

Table 6.1: Typical cable characteristics

	Exchange Cable	Main Cable	Distribution Cable	Installation Cable
Wire diameter (mm)	0,5; 0,6; 0,32; 0,4	0,3 - 1,4	0,3 - 1,4	0,4; 0,5; 0,6; 0,8; 0,9; 0,63
Structure	SQ (B) or TP (L)	SQ (B) or TP (L)	SQ (B) or TP (L)	SQ or TP or UP
Maximum number of pairs	1 200	4 800	600	2 (aerial) 600 (in house)
Installation		underground in ducts	underground or aerial	aerial (drop) or in ducts (in house)
Capacitance (nF/km at 800 Hz)	55 ... 120	25 ... 60	25 ... 60	35 ... 120
Wire insulation	PVC, FRPE	PE, paper pulp	paper, PE, Cell PE	PE, PVC
TP:	Twisted Pairs	PE:	Polyethylene	
SQ:	Star Quads	PVC:	Polyvinylchloride	
UP:	Untwisted Pairs	Pulp:	Pulp of paper	
L:	Layer	Cell PE:	Cellular Foam	
B:	Bundles (units)	FRPE:	Polyethylene	
			Fire Resistant PE	
NOTE: This table is intended to describe the cables presently installed in the local loop. Not all of the above cable types are suitable for SDSL systems.				

6.3 Electrical characteristics of a digital local line (DLL)

The transmitted signal will suffer from impairments due to crosstalk, impulsive noise and the non-linear variation with frequency of DLL characteristics. These impairments are described in more detail in the following subclauses.

6.3.1 Principal transmission characteristics

The principal electrical characteristics varying nonlinearly with frequency are:

- insertion loss;
- group delay;
- characteristic impedance, comprising real and imaginary parts.

6.3.2 Crosstalk characteristics

Crosstalk noise in general is the result of finite coupling loss between pairs sharing the same cable, especially those pairs that are physically adjacent. Finite coupling loss between pairs causes a vestige of the signal flowing on one DLL (disturber DLL) to be coupled into an adjacent DLL (disturbed DLL). This vestige is known as crosstalk noise. Near-end crosstalk (NEXT) is assumed to be the dominant type of crosstalk.

Intersystem NEXT results when pairs carrying different digital transmission systems interfere with each other.

Intrasystem NEXT or self-NEXT results when all pairs interfering with each other in a cable are carrying the same digital transmission system. Intrasystem NEXT noise coupled into a disturbed DLL from a number of DLL disturbers can be represented as being due to an equivalent single disturber DLL with a coupling loss versus frequency characteristics known as Power Sum Loss (PSL). Values for 1 % worst case NEXT loss vary from 40 dB to 70 dB at 150 kHz depending upon the cable type, number of disturbers and environment.

6.3.3 Unbalance about earth

The DLL will have finite balance about earth. Unbalance about earth is described in terms of longitudinal conversion loss (LCL). The expected worst case value is 42,5 dB at 150 kHz decreasing with frequency by 5 dB/decade.

6.3.4 Impulse noise

The DLL will have impulse noise resulting from other systems sharing the same cables as well as from other sources.

6.3.5 Micro interruptions

A micro interruption is a temporary line interruption due to external mechanical action on the copper wires constituting the transmission path, for example, at a cable splice.

6.4 Minimum digital local line (DLL) requirements for SDSL applications

- No loading coils.
- Only twisted pair or quad cable.
- No additional shielding necessary.
- When bridged taps are present, the maximum number shall be limited to 2 and the length of each to 500 m.

7 Frame structure and bit rates

7.1 Introduction

This subclause describes the proposed SDSL frame structure before scrambling and encoding. This structure is valid during normal operation after symbol timing synchronization, frame alignment and after all internal transceiver coefficients have been stabilized sufficiently to permit a reliable transport of the signals.

The frame structure provides the flexibility to transport variable payload bit rates from 192 kbit/s up to 2 312 kbit/s and the option of plesiochronous or synchronous mode.

In plesiochronous mode the SDSL transceiver clock is independent of the incoming data clock, it may be derived from the free running local oscillator or from an external clock source. The data is mapped to the SDSL frame employing the HDSL stuffing procedure. Each individual frame contains either 0 or 4 stuffing bits resulting in a variable frame length. The mean length of the SDSL frames is 6 ms.

In synchronous mode the SDSL transceiver clock is locked to the clock of the transmit data. The SDSL frames have a fixed length of 6 ms. Instead of the stuffing bits, two spare bits are defined at the end of each frame.

7.2 General structure of SDSL frames

Figure 7.1 illustrates bit sequences of the SDSL frame structure prior to scrambling at the transmit and after descrambling at the receive side.

The nominal SDSL frame length is 6 ms. The frame is subdivided into four groups. The first group of the frame starts with the 14 bit long synchronization word followed by two SDSL overhead bits and 12 blocks of SDSL payload. Each payload block consists of $i + n * 8$ bits ($i = 0..7$, $n = 3..36$) according to the number of B-channels (n) and Z-bits (i) (service, signalling, maintenance) which are transmitted. Depending on the payload bit rate each block contains between 24 and 289 bits. The default number of Z-bits is one. For $i = 1$ and $n = 36$ compatibility with the HDSL frame of TS 101 135 [2] is achieved.

The three groups following the first group all have the same structure. Each consists of ten SDSL overhead bits and 12 SDSL payload blocks as described above. So one frame contains a 14 bit synchronization word, 32 overhead bits, and between 1 152 and 13 872 payload bits. (The total number of bits in one 6 ms frame is $48*(1 + i + n*8)$ [bits]. The corresponding data rates are between 192 kbit/s + 8 kbit/s and 2 312 kbit/s + 8 kbit/s). There are two possibilities for the bits that occur at the end of the frame (after the P48 block). If bit stuffing is used, either zero or four stuffing bits are inserted. If bit stuffing is not used, two spare bits are available.

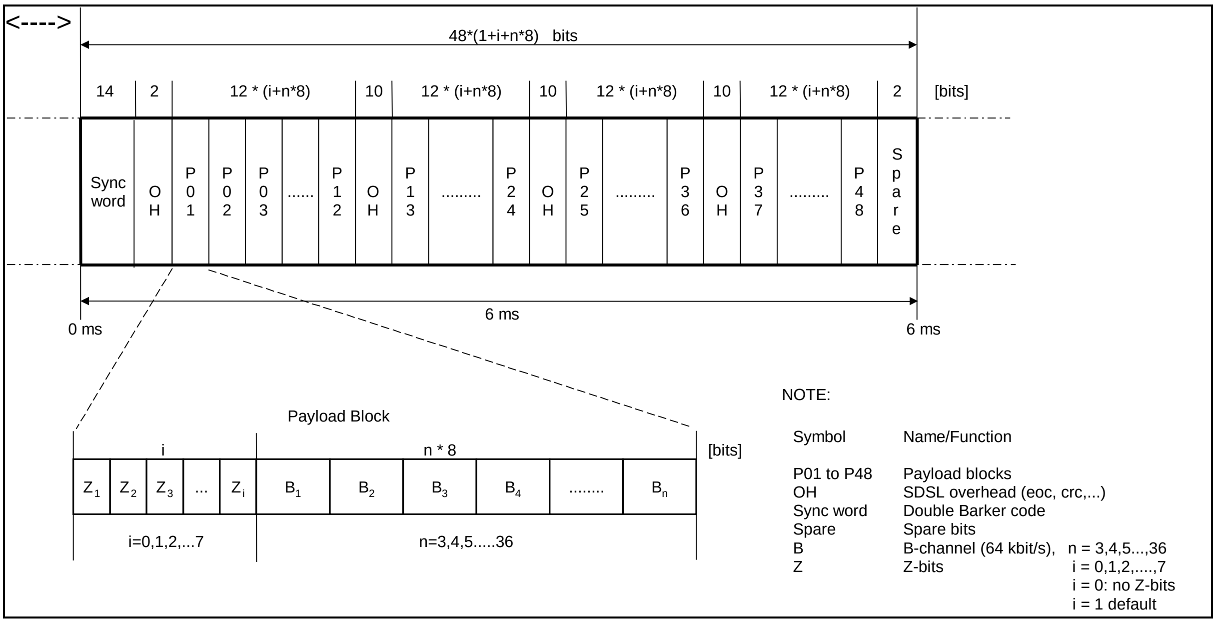
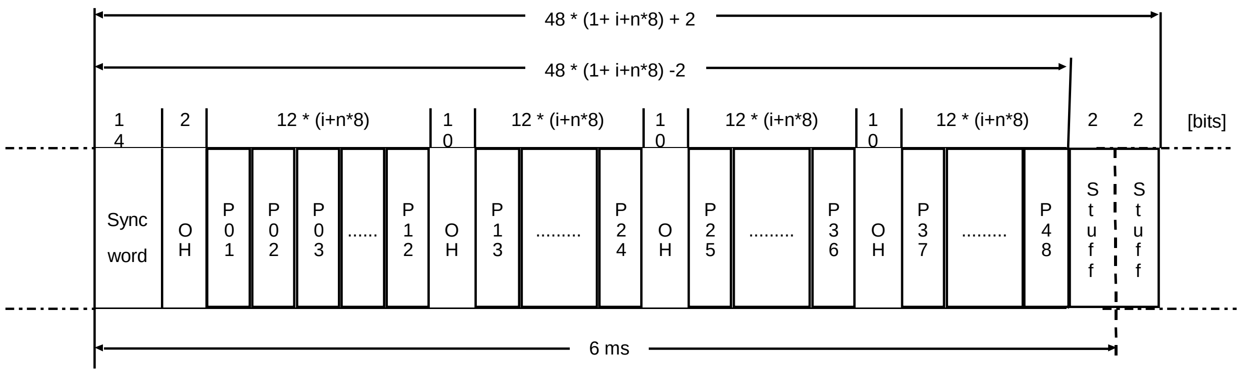


Figure 7.1: SDSL frame structure

7.3 Frame structures for synchronous and plesiochronous transmission

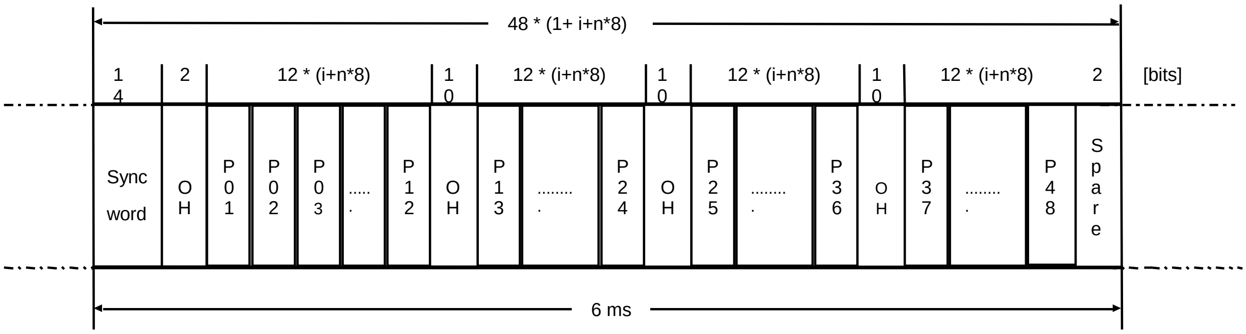
Figure 7.2 and figure 7.3 show the general structure of the SDSL frames for plesiochronous and for synchronous transmission.



NOTE:	Symbol:	Name/Function:
	P01 to P48	Payload blocks.
	OH	SDSL overhead (eoc, crc, ...).
	Sync word	Double Barker code.
	Stuff	Stuffing bits.

Figure 7.2: SDSL frame structure for plesiochronous transmission

In plesiochronous mode either zero or four stuffing bits are inserted at the end of each frame. The average frame length is 6 ms. Due to the insertion of the stuffing bits the real length of the frame varies and is 6ms ± ((2 × 6)/(Number of bits in frame)) [ms]. Thus the real frame length also is dependent on the data rate.



NOTE: Symbol: Name/Function:
P01 to P48 Payload.
OH SDSL overhead (eoc, crc,...).
Sync word Double Barker code.
Spare Spare bits.

Figure 7.3: SDSL frame structure for synchronous transmission

The SDSL frame for synchronous transmission (see figure 7.3) is almost the same as described above. The only difference is the spare bits at the end of the frame which replace the stuffing bits. These SDSL frames are always 6 ms long. Instead of the zero or four stuffing bits two spare bits are always available at the end of each frame in order to equal the average length of (plesiochronous) SDSL frames.

7.4 Determination of bit rates

Table 7.1 shows the relationship between the payload bit rate and the line bit rate.

Table 7.1: Bit rates

Bit Type	Channel Type	Number of bits in one frame of 6 ms	Bit rate
Frame bits	Overhead	48/48 ± 2	8 kbit/s
Payload bits	B-channel (n × 64 kbit/s) (n = 3...36)	n × 48 × 8	n × 64 kbit/s
	Z-bits (i × 8 kbit/s) (i = 0...7)	i × 48	i × 8 kbit/s
Total number of bits in frame		48 × (1 + i + n × 8)	(n × 64 + i × 8 + 8) kbit/s

The minimum and maximum values possible for the line bit rate are:

- Minimum (i = 0; n = 3) 192 kbit/s + 8 kbit/s = 200 kbit/s.
- Maximum (i = 1; n = 36) 2 304 kbit/s + 8 kbit/s + 8 kbit/s = 2 320 kbit/s.

7.5 Tolerance of the line symbol rate

The jitter requirements of the reference clocks have to be specified. The tolerance of the line symbol rate in the plesiochronous mode shall be ±50 PPM, as well in the local as in the network reference version (see subclause 7.6).

7.6 Reference clock architecture

Due to the multiple applications and variable bit rates called for in SDSL, a flexible clocking architecture is required. The LTU and NTU symbol clocks are described in terms of their allowed synchronization references. Other clock domains may be accommodated via the supported bit-stuffing mechanism or by using other methods of clock information transport (as in the ISDN-BA narrowband transport option).

The SDSL reference configuration permits the flexibility to provide a symbol clock reference based on the sources shown in figure 7.4. These sources may be chosen independently in the up and downstream directions (with bit stuffing employed as required by the application). The clock accuracy and jitter requirements are specified in a separate subclauses or application dependent annexes. Figure 7.4 illustrates the clock reference options in the context of a simplified SDSL reference model. Table 7.2 lists the normative synchronization configurations as well as example applications.

The clock domain of embedded ISDN-BA channels may be different from that of the data channel. In this case separate stuffing and framing procedures have to be provided for these channels, which shall be described in the relevant application dependent annex.

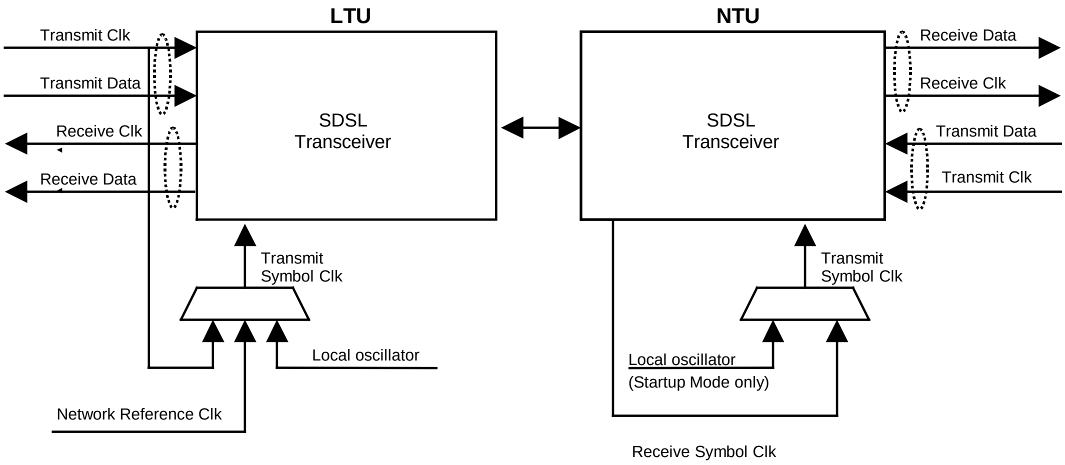


Figure 7.4: SDSL Symbol Clock Synchronization References

Table 7.2: SDSL symbol clock synchronization configurations

Mode No.	LT symbol clock source	NT symbol clock source	Example application	Mode
1	Local oscillator	Received symbol clock	"Classic" HDSL	Plesiochronous
2	Network reference	Received symbol clock	"Classic" HDSL with embedded timing reference.	Plesiochronous with timing reference
3a (note)	Transmit data clock	Received symbol clock	Main application is synchronous transport in both directions.	Synchronous
3b (note)	Transmit data clock	Received symbol clock	Synchronous downstream transport and bit-stuffed upstream is also possible.	downstream: synchronous upstream: plesiochronous
NOTE: Both modes 3a and 3b are possible with the same clock sources depending on clock tolerances.				

7.7 Frame bit assignments

In table 7.3 the bit sequence of SDSL frame prior to scrambling at the transmit side and after descrambling at the receive side is presented. While the frame structures are identical in both directions of transmission, the functional assignments of individual bits in the direction LTU to NTU or NTU to LTU are different. Unused bits in either direction shall be set to ONE. For example the proposed NTU local power status bit is defined only in the frame transmitted towards the LTU and the corresponding bit position in the reverse direction has no assignment.

The value k is defined as $k = i + n \times 8$.

Table 7.3: SDSL Frame Structure

Time	Frame Bit #	OH Bit #	Abr. Name	Full Name	NOTEs
0 ms	1-14	1-14	SW 1-14	Sync word	
	15	15	fbit1	losd - loss of input signal at the far end application interface	
	16	16	fbit2	sega - segment anomaly	
	17- 12 k + 16	----------	B01-B12	Payload blocks 1-12	SDSL payload including Z-bits
	12 k + 17	17	eoc01	eoc message bit 1	
	12 k + 18	18	eoc02	eoc message bit 2	
	12 k + 19	19	eoc03	eoc message bit 3	
	12 k + 20	20	eoc04	eoc message bit 4	
	12 k + 21	21	crc1	cyclic redundancy check	CRC-6
	12 k + 22	22	crc2	cyclic redundancy check	CRC-6
	12 k + 23	23	fbit3	ps - NTU local power status bit	NTU -------> LTU only
	12 k + 24	24	sbid1	Stuffing indicator bit 1	spare in synchronous mode
	12 k + 25	25	eoc05	eoc message bit 5	
	12 k + 26 -	26	eoc06	eoc message bit 6	
	12 k + 27 - 24 k + 26	---------	B13-B24	Payload blocks 13-24	SDSL payload including Z bits
	24 k + 27	27	eoc07	eoc message bit 7	
	24 k + 28	28	eoc08	eoc message bit 8	
	24 k + 29	29	eoc09	eoc message bit 9	
	24 k + 30	30	eoc10	eoc message bit 10	
	24 k + 31	31	crc3	cyclic redundancy check	CRC-6
	24 k + 32	32	crc4	cyclic redundancy check	CRC-6
	24 k + 33	33	fbit4	segd - segment defect	
	24 k + 34	34	eoc11	eoc message bit 11	
	24 k + 35	35	eoc12	eoc message bit 12	
	24 k + 36	36	sbid2	Stuffing indicator bit 2	spare in synchronous mode
	24 k + 37 – 36 k + 36	----------	B25-B36	Payload blocks 25-36	SDSL payload including Z bits
	36 k + 37	37	eoc13	eoc message bit 13	
	36 k + 38	38	eoc14	eoc message bit 14	
	36 k + 39	39	eoc15	eoc message bit 15	
	36 k + 40	40	eoc16	eoc message bit 16	
	36 k + 41	41	crc5	cyclic redundancy check	CRC-6
	36 k + 42	42	crc6	cyclic redundancy check	CRC-6
	36 k + 43	43	eoc17	eoc message bit 17	
	36 k + 44	44	eoc18	eoc message bit 18	
	36 k + 45	45	eoc19	eoc message bit 19	
	36 k + 46	46	eoc20	eoc message bit 20	

Time	Frame Bit #	OH Bit #	Abr. Name	Full Name	NOTEs
6 + 12/(number of bits in frame) ms	36 k + 47 – 48 k + 46	----------	B37-B48	Payload blocks 37-48	SDSL payload including Z bits
	48k + 47	47	stb1/spa1	Stuff/spare bit 1	Frame stuffing / spare in synch mode
6 ms nominal	48 k + 48	48	stb2/spa2	Stuff/spare bit 2	Frame stuffing / spare in synch mode
	48 k + 49	49	stb3	Stuff bit 3	Frame stuffing / not present in synch mode
6 + 12/(number of bits in frame) ms	48 k + 50	50	stb4	Stuff bit 4	Frame stuffing / not present in synch mode

The following gives a short description of the currently defined overhead bits.

- **Sync word:**
    - the synchronization word (SW) enables the SDSL receivers to acquire frame alignment. The synchronization word consists of the following 14-bit sequence: 11111100001100;
    - the SW is present in every frame and is the same in both the upstream and downstream directions.
- **losd-bit (loss of signal):**
    - if there is no signal from the application interface, the losd-bit shall be set to ZERO in the next frame towards the far end. Under normal conditions, this bit shall be set to ONE.
- **sega (segment anomaly):**
    - the sega-bit shall be used to indicate CRC-errors on the incoming SDSL frames. It is set to ZERO if CRC-errors are detected and to ONE in normal operation.
- **segd (segment defect):**
    - the segd-bit shall be used to indicate loss of synchronization on the incoming SDSL frames. It is set to ZERO if loss of synchronization is detected and to ONE in normal operation.
- **eoc-bits (embedded operations channel):**
    - 20 bits (eoc01...eoc20) are provided as a separate maintenance channel. For a description of codes and the messaging procedure in this channel (see subclause 8.4).
- **crc-bits:**
    - the SDSL frame shall have six bits assigned to a cyclic redundancy check (CRC) code. The CRC is generated for each transmitted frame, then transmitted in the following frame.

The six crc-bits transmitted in the $(N + 1)^{th}$ frame shall be determined as follows:

1 all bits of the N^{th} frame except the fourteen sync word bits, the six crc-bits and any stuffing bits, for a total of m bits, are used, in order of occurrence, to construct a polynomial in "X" such that bit "0" of the N^{th} frame is the coefficient of the term X^{m-1} and bit m-1 of the N^{th} frame is the coefficient of the term X^0;

2 the polynomial is multiplied by the factor X^6, and the result is divided, modulo 2, by the generator polynomial $X^6 \oplus X \oplus 1$. The coefficients of the remainder polynomial are used, in order of occurrence, as the ordered set of check bits, crc1 through crc6, for the $(N + 1)^{th}$ frame. The ordering is such that the coefficient of the term X^5 in the remainder polynomial is check bit crc1 and the coefficient of the term X^0 in the remainder polynomial is check bit crc6;

3 the check bits, crc1 through crc6, contained in a frame are those associated with the content of the preceding frame. When there is no immediately preceding frame, the check bits may be assigned any value.

- **ps-bit (power supply bit):**
  - the power supply bit ps is used to indicate the status of the local power supply in the NTU. The power status bit is set to ONE if power is normal and to ZERO if the power has failed;
  - on loss of power at the NTU, there shall be enough power left to communicate three "Power Loss" messages towards the LTU. Regenerators shall pass this bit transparently.

  sbid (stuff indicator bits):
  - (sbid1, sbid2);
  - these bits are only needed in plesiochronous mode and are spare in synchronous mode. These stuff indicator bits indicate whether or not a stuffing event has occurred in the frame. Both bits shall be set to 1 if the 4 stuff bits are present at the end of that frame. Both bits shall be set to 0 if there are no stuff bits at the end of the current frame.
- **stb (stuffing bits):**
  - (stb1, stb2, stb3, stb4);
  - these bits are only needed in plesiochronous mode and are spare in synchronous mode. They are always used together. Either zero or four stuffing bits are inserted, depending on the relation of the timing. If not used the stuffing bits shall be set to ONE;
  - spa (spare bits);
  - (spa1, spa2).

These bits are only available in synchronous mode and always used together.

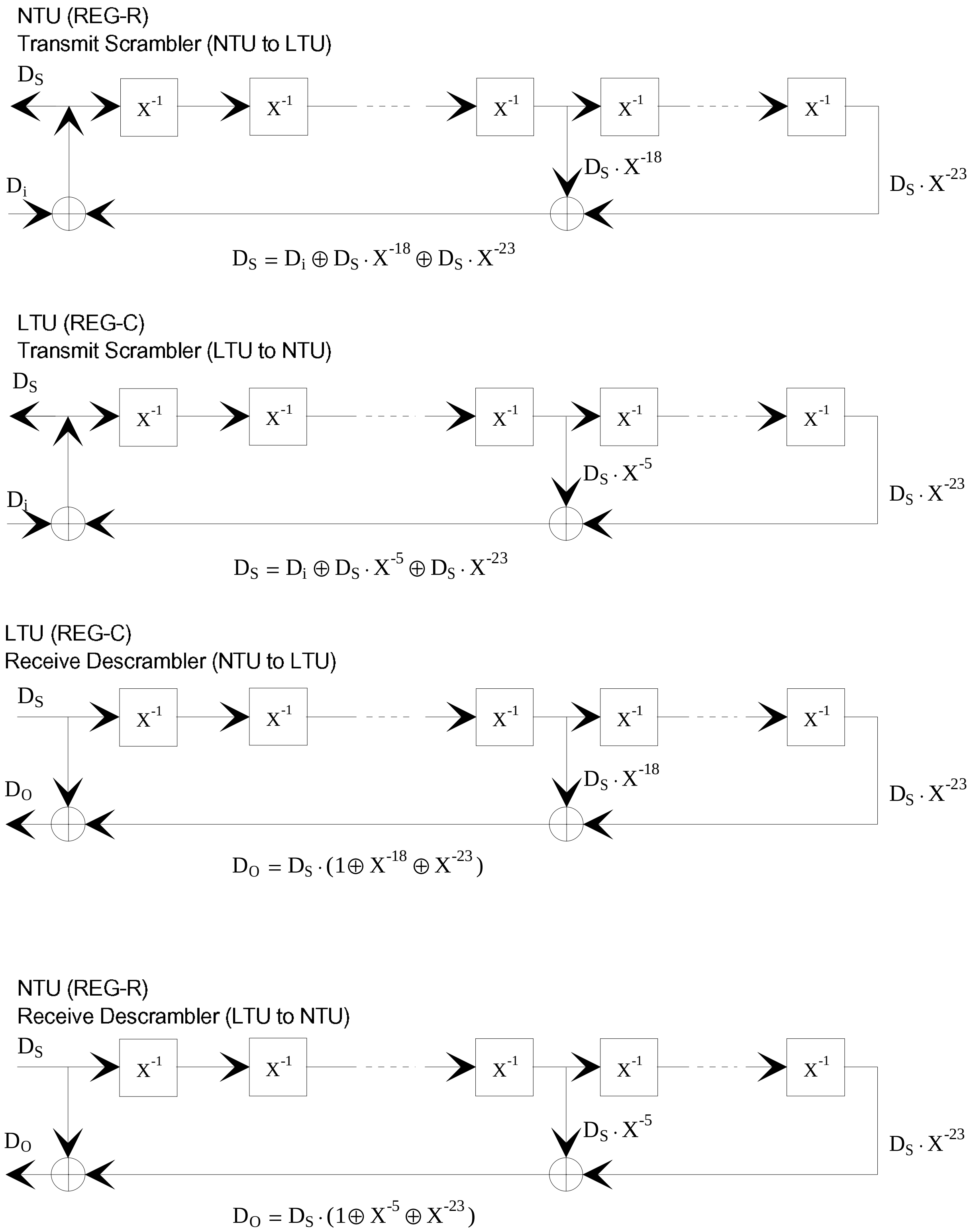
7.8 Scrambling method

SDSL transceiver systems use the same self synchronizing scrambling as the 2B1Q transmission system for ISDN-BA as defined in TS 102 080 [3] annex A and HDSL as defined in TS 101 135 [2]. The data stream with exception of the 14 bits of the sync word and the stuffing bits is scrambled by means of a 23rd-order polynomial prior to encoding.

Table 7.4: Scrambler polynominals

Transmit direction	Polynominal	Scrambler/Descrambler
NTU → LTU	$x^{-23} \oplus x^{-18} \oplus 1$	Transmit NTU Receive LTU
LTU → NTU	$x^{-23} \oplus x^{-5} \oplus 1$	Transmit LTU Receive NTU
NOTE: The sign ⊕ stands for modulo 2 summation.		

Figure 7.5 shows block diagrams for the scramblers and the descramblers and that the binary data stream is recovered in the receiver by applying the same polynominal used for scrambling to the scrambled data.



$D_S =$ scrambled (s) data

$D_i =$ unscrambled input (i) data

$D_O =$ unscrambled output (o) data

X^{-n} = delay of n bit periods

$\oplus$ = logical exclusive or

$\cdot$ = multiplication

Figure 7.5: Scramblers and descramblers

8 Operation and maintenance

8.1 Management Reference Model

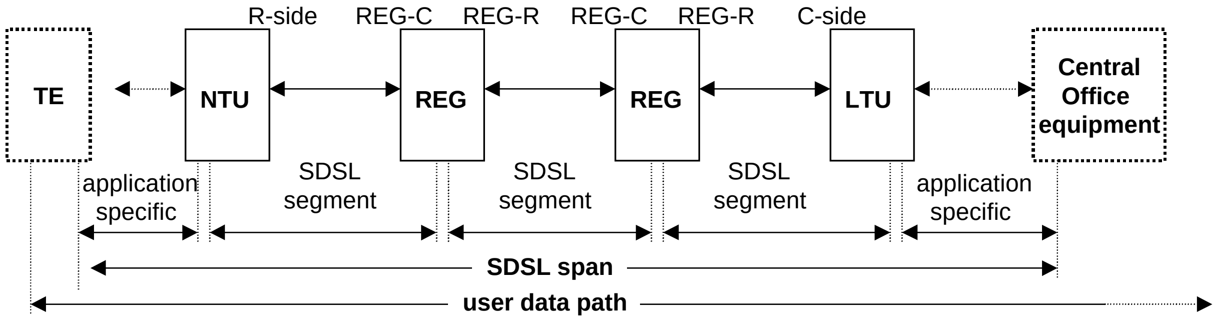


Figure 8.1: Management Reference Model

Figure 8.1 shows the management reference model for user data transport over SDSL. This example includes two regenerator units for informative purposes. The presence of two regenerators is not intended to be a requirement or limit. An SDSL segment is characterized by a metallic transmission medium utilizing an analog coding algorithm, which provides both analog and digital performance monitoring at the segment entity. An SDSL segment is delimited by its two end points, known as segment terminations. An SDSL segment termination is the point at which the analog coding algorithms end and the subsequent digital signal is monitored for integrity.

All SDSL performance monitoring data is transported over the eoc. The fixed indicator bits in the SDSL frame *losd*, *sega*, *segd* and *ps* are used for rapid communication of interface or SDSL segment defects, which may lead to protection switching. In addition, the fixed indicator bits may be used for rapid alarm filtering SDSL segment failures.

8.2 SDSL Primitives and Failures

8.2.1 Cyclical Redundancy Check Anomaly (CRC)

A CRC anomaly shall be declared when the crc-bits generated locally on the data in the received SDSL frame do not match the crc-bits (*crc1 - crc6*) received from the transmitter. A CRC anomaly only pertains to the frame over which it was declared.

8.2.2 Segment Anomaly (SEGA)

An upstream segment anomaly shall be declared when any signal regenerator declares a CRC anomaly for an SDSL frame moving in the direction from NTU to LTU. A downstream segment anomaly shall be declared when any signal regenerator declares a CRC anomaly for an SDSL frame moving in the direction from LTU to NTU. A segment anomaly indicates that a regenerator operating on a segment has received corrupted data and therefore the regenerated data is unreliable. The purpose of segment anomaly is to ensure internal SDSL PMD integrity; it is not intended to be reported to an external management entity. A segment anomaly is indicated via the *sega*-bit in the SDSL frame.

8.2.3 Loss of Sync Defect (LOSW defect)

This defect is indicated in the eoc through message ID 140 and from regenerators additionally through *segd*-bit.

In plesiochronous mode, an LOSW defect shall be declared when at least 3 consecutive received frames contain one or more errors in the framing bits. The term framing bits shall refer to that portion of *Sync word*, *stuffing bits* and *stuff indicator bits*, which are used for frame synchronization. An LOSW defect shall be cleared when at least 2 consecutive received frames contain no errors in the framing bits.

In synchronous mode, an LOSW defect shall be declared when 3 consecutive received frames contain CRC anomalies.

8.2.4 Segment Defect (SEGD)

An upstream segment defect shall be declared when any signal regenerator declares a LOSW defect for data moving in the direction from NTU to LTU. A downstream segment defect shall be declared when any signal regenerator declares a LOSW defect for data moving in the direction from LTU to NTU. A segment defect indicates that a regenerator has lost SDSL synchronization and therefore the regenerated data is unavailable. A segment defect shall be cleared when all regenerators have no LOSW defects. This primitive is typically reported to an external management entity and is used to ensure timely protection switching, alarm filtering, etc. A segment defect is indicated via the *segd*-bit in the SDSL frame.

8.2.5 Loss of Sync Word Failure (LOSW failure)

This defect is indicated in the eoc through message ID 141 and from regenerators additionally through *segd*-bit.

An LOSW failure shall be declared after 2,5 ± 0,5 seconds of contiguous LOSW defect. The LOSW failure shall be cleared when the LOSW defect is absent for 20 seconds or less (i.e., clear within 20 seconds.) The minimum hold time for indication of LOSW failure shall be 2 seconds.

8.2.6 Loss of local power

The NTU shall indicate loss of local power to the LTU through ps - bit. The NTU shall be able to send the ps-bit in at least 3 consecutive frames after loosing local power.

8.3 Performance data storage

Performance history for all SDSL segment endpoints shall be maintained at the LTU.

An SDSL Errored Second should be defined as a 1 second interval during which one or more CRC anomalies are declared and/or one or more LOSW defects are declared.

An SDSL Severely Errored Second should be defined as a 1 second interval during which at least 50 CRC anomalies are declared or one or more LOSW defects are declared (50 CRC anomalies are equivalent to a 30 % errored frame rate for a nominal frame length).

An SDSL Unavailable Second (UAS) should be defined as a 1 second interval during which a LOSW failure has been declared.

In order to monitor ES and SES, each SDSL element shall maintain a 1 second timer and an 8 bit modulo counter for each receiver. (An NTU or LTU shall have 1 counter. A signal regenerator shall have 2 counters.) The corresponding counter shall be incremented for every ES or SES that is declared.

The LTU should maintain performance history registers for each SDSL segment endpoint. The performance history registers should be the following counters:

- SDSL CRC Anomaly count;
- SDSL Errored Seconds - current 15 minute period, 32 previous 15 minute periods, current 24 hour period, 7 previous 24 hour periods;

- SDSL Severely Errored Seconds - current 15 minute period, 32 previous 15 minute periods, current 24 hour period, 7 previous 24 hour periods;
- SDSL Unavailable Seconds - current 15 minute period, 32 previous 15 minute periods, current 24 hour period, 7 previous 24 hour periods.

8.4 SDSL embedded operations channel (eoc)

8.4.1 *eoc* management reference model

The LTU shall maintain a management information database for external access by network management or via craft terminal interface.

Optionally, the NTU may maintain a management information database, which can be locally accessed (through a craft terminal interface). This is particularly useful when the LTU, due to fault conditions, is unreachable via the eoc.

Access to the management information database from craft terminal interfaces on attached units shall be provided through a virtual terminal interface.

8.4.2 eoc overview and reference model

The eoc allows terminal units to maintain information about the span. There are two basic flows of data, differentiated by which terminal unit initiates the data flow (and subsequently stores the information for external access.) The data flow initiating from the LTU is mandatory. The data flow initiating from the NTU is optional, but all units shall respond to requests in either direction of data flow. In all cases the "master database" shall be stored at the LTU and all conflicts shall be resolved in favour of the LTU (i.e., the information at the LTU takes precedence). The data flows are illustrated in table 8.1 for a 2 regenerator link (Q denotes a query or command message, R denotes a response message). Up to 8 regenerators are supported by the protocol definition. Asterisks denote optional message transmissions.

Table 8.1: Illustration of eoc flow with 2 regenerators

Messages from LTU Msg(src,dest)	Messages from REG1 Msg(src,dest)	Messages from REG2 Msg(src,dest)	Messages from NTU Msg(src,dest)
Q(1,3) →	→ Process		
Process ←	← R(3,1)		
Q(1,4) →	→ Forward →	→ Process	
Process ←	← Forward ←	← R(4,1)	
Q(1,2) →	→ Forward →	→ Forward →	→ Process
Process ←	← Forward ←	← Forward ←	←R(2,1)
		Process ←	←Q(2,3)*
		R(3,2) →	→ Process
	Process ←	← Forward ←	←Q(2,4)*
	R(4,2) →	→ Forward →	→ Process
Process ←	← Forward ←	← Forward ←	←Q(2,1)*
R(1,2) →	→ Forward →	→ Forward →	→ Process
NOTE: *indicates optional messages.			

The data link layer of SDSL eoc checks the FCS and if valid passes the packet to the network layer. If the CRC is invalid the entire packet is ignored. The network layer consists of three possible actions: Process, Forward, and Ignore/Terminate. Process means that the source address and HDLC information field are passed on to the application layer. Forward means that the packet is sent onward to the next SDSL element.

NOTE: Only REGs will forward packets.

Ignore/Terminate means that the HDLC packet is ignored and is not forwarded. An REG may both process and forward a packet in the case of a broadcast message. If the segment is not active in the forwarding direction, the REG shall discard the packet instead. When the segment is active in the forwarding direction, the maximum forwarding delay in an REG shall be 300 ms. All retransmission and flow control is administered by the LTU or NTU.

To accommodate the dual data flows, SDSL regenerators have dual addresses as shown in table 8.1. One address is for communication with the LTU and the other address is for communication with the NTU. During Discovery, the LTU and optionally the NTU send discovery probe messages, which propagate across the span and allow the REGs to be numbered via a hop count field in the message. This process is explained in detail below.

The SDSL terminal units communicate unidirectionally and thus have only one address. The LTU is assigned a fixed address of 1 and the NTU is assigned a fixed address of 2. At power-up, each REG is assigned the address of 0 for each direction. Under a LOSW failure condition, the REG shall reset its source address to 0 for the direction in which the LOSW failure exists. The REG source address shall be changed from 0 if and only if a discovery probe message is received and processed. In this way, a regenerator will only communicate in the direction of a database. For instance, if a regenerator receives a probe message from the LTU and not from the NTU then its address will remain 0 in the direction towards the remote.

8.4.3 eoc start-up

After loop activation, the SDSL eoc goes through three initialization stages: Discovery, Inventory and Configuration. During Discovery, the LTU and optionally the NTU will learn if any mid-span regenerators exist and their addresses will be determined. During Inventory, the LTU will poll each REG and the NTU to establish inventory information on each element for the terminal unit's database. (Similarly, the NTU may poll each REG and the LTU to establish its own database, although this is optional.) During Configuration, the LTU configures the NTU and any REGs for alarm thresholds, signal characteristics, etc. There is no enforcement of the order or time of the Inventory and Configuration phases; the initiating LTU or NTU is in control.

The following table is an example of Discovery starting from the LTU and then followed by an optional Discovery initiated by the NTU. Although these are shown sequentially in this example, they are actually independent; it is not necessary for the NTU to wait until it received the probe from the LTU before initiating its own Discovery phase. The NTU may send its probe as soon as its eoc is active. The Discovery Response contains the current hop count, the vendor ID, eoc version and an indication of LOSW in the forward direction (i.e., in the direction of eoc flow that is opposite to the direction that the Discovery Response is sent).

Table 8.2: Illustration of eoc discovery phase

Messages from LTU Msg(src,dest,h)	Messages from REG1 Msg(src,dest,h)	Messages from REG2 Msg(src,dest,h)	Messages from NTU Msg(src,dest,h)
DP(1,0,0)→			
	← DR(3,1,1)		
	DP(0,0,1)→		
	←Forward ←	← DR(4,1,2)	
		DP(0,0,2)→	
	←Forward ←	←Forward ←	← DR(2,1,3)
			← DP(2,0,0)
		DR(3,2,1)→	
		← DP(4,0,1)	
	DR(4,2,2)→	→Forward →	
	← DP(3,0,2)		
DR(1,2,3) →	→Forward →	→Forward →	
NOTE: h = hop count, DP = Discovery Probe, DR = Discovery Response).			

After the initiator (LTU and optionally NTU) has received a Discovery Response message from an element, it shall then begin the Inventory phase for that particular element. This is accomplished by polling that particular element for its inventory information. After the initiator has received the inventory information for a unit, it shall then begin the Configuration phase by sending the appropriate configuration information to the corresponding element. The Inventory and Configuration phases operate independently for each responding terminal/regenerator unit.

To ensure interoperability, the behaviour of slave or responding units is carefully specified by the present document. The particular method for handling dropped packets or no response is left to the discretion of the initiating LTU or NTU.

Table 8.3 shows the eoc state table for the network side of an REG.

NOTE: An identical, but independent, state machine exists for the customer side of an REG to support messages originating from the NTU.

The state machine consists of 3 states: Offline, Discovery, and eoc Online. The Offline state is characterized by LOSW failure (a loss of SDSL sync). The Discovery state is characterized by an unknown address. Once the address is learned through the Discovery message, the REG enters the eoc online or active state. At this point, the REG will respond to inventory, configuration, maintenance, or other messages from the LTU.

Table 8.3: REG network eoc state table

Offline state

Event	**Action**
Network LOSW = 0.	eoc state = Discovery Ready.

Discovery Ready state

Event	Action
Network LOSW = 1.	Network eoc address = 0. Network eoc state = offline.
Discovery probe message received from the network side.	Increment hop count Set network eoc address to hop count + 2. Compose and present Discovery message to customer side application layer. Send Discovery response to LTU. Network eoc state = eoc online.
Message forwarding requested from customer side.	Send requested message toward network if eoc idle.

eoc Online state

Event	**Action**
Network LOSW = 1.	Network eoc Address = 0. Network eoc State = Offline.
Discovery message received from the network side.	Increment hop count Set network eoc address to hop count + 2. Compose and present Discovery message to customer side application layer. Send Discovery Response to LTU.
Message with broadcast destination address received from the Network side.	Process the message. Request the customer side eoc network layer to forward the message.
Message with unit's destination address or address 0 received from the network side.	Process the message.
Message with address not equal to unit's address received from the network side.	Request forwarding of message from the customer side network layer.
Message forwarding requested from customer side network layer.	Send requested message toward network as soon as eoc available.

8.4.4 Remote management access

The LTU shall maintain the master management database for each SDSL segment (an optional second database is maintained at the NTU). Other units are only required to store enough information to accurately send information via the eoc. The information contained in the master database shall be accessible from any SDSL unit that has a craft terminal port and from network management if it is available. The craft terminal access is in the form of a virtual terminal interface (or virtual craft terminal interface). This interface is defined so that it can be used by any attached unit to access the terminal screen of another unit. Support for this feature is optional, with the exception of the LTU, which shall support the host side of at least one remote terminal connection (whether this interface can be active simultaneously with local craft terminal access to the LTU is a vendor decision and beyond the scope of this Technical Specification). The virtual terminal interface consists of connect, disconnect, keyboard, and screen messages. After a connection has been established, input characters from the craft terminal port are sent in keyboard data messages to the host unit. The host unit, in turn, shall send information in the form of ASCII text and ASCII control codes, and screen control functions in screen messages, whose contents are transmitted back to the craft terminal port. The host unit shall echo characters.

The method for determining that remote access through the local craft terminal port is desired or should be terminated is vendor specific, and beyond the scope of this Technical Specification. Whatever method is used, capability for transmitting all valid key sequences (ASCII characters and control codes) shall be provided.

8.4.5 eoc transport

The eoc shall be transported in the SDSL frame in bits *eoc1* through *eoc20*. Five octets are contained in each two SDSL frames, with specified alignment. The least significant bit (LSB) of the octets are located in bits 1, 9, and 17 of the eoc bits in the first frame and bits 5 and 13 of the second frame; each octet is transmitted LSB first. Octet alignment across frames is achieved through detection of the alignment of the HDLC sync pattern ($7E_{16}$).

8.4.5.1 eoc data format

Numerical data and strings are placed in the eoc with octet alignment. Data items that are not an integral number of octets may be packed together to minimize message sizes.

Numerical fields shall be transmitted most significant octet first, least significant bit first within an octet.

Strings shall be represented in the data stream with their first character (octet) transmitted first. Strings shall be padded with spaces or terminated with a NULL (00_{16}) to fill the allocated field size. String fields are fixed length so characters after a NULL in a string data field are "don't care".

8.4.5.2 eoc frame format

The eoc channel shall carry messages in an HDLC-like format as defined in ITU-T Recommendation G.997.1 [8], subclause 6.2. The channel shall be treated as a stream of octets; all messages shall be an integral number of octets.

The frame format uses a compressed form of the HDLC header, as illustrated in table 8.4. The destination address field shall be the least significant 4 bits of octet 1; the source address field shall occupy the most significant 4 bits of the same octet (the address field.) There is no control field. One or more sync octets ($7E_{16}$) shall be present between each frame. Inter-frame fill shall be accomplished by inserting sync octets as needed. Discovery probe messages shall be preceded by at least <TBD> sync octets to assure proper detection of octet alignment. The Information Field contains exactly one message as defined below. The maximum length of a frame shall be 75 octets, not including the sync pattern or any octets inserted for data transparency.

Table 8.4: Frame format for SDSL eoc

	MSB	**LSB**	
Octet #	Contents		
	Sync pattern ($7E_{16}$)		
1	Source address bits 7..4	Destination address bits 3..0	
2	Message ID per Table		information
	Message content - octet 1		field
	…		…
	Message content - octet L		…
L + 3	FCS octet 1		
L + 4	FCS octet 2		
	Sync pattern ($7E_{16}$)		

8.4.5.3 Data transparency

Transparency for the information payload to the sync pattern ($7E_{16}$) and the control escape pattern ($7D_{16}$) shall be achieved by octet stuffing.

Before transmission:

- octet pattern ($7E_{16}$) is encoded as two octets ($7D_{16}$), ($5E_{16}$);
- octet pattern ($7D_{16}$) is encoded as two octets ($7D_{16}$), ($5D_{16}$);

At reception:

- octet sequence ($7D_{16}$), ($5E_{16}$) is replaced by octet ($7E_{16}$);
- octet sequence ($7D_{16}$), ($5D_{16}$) is replaced by octet ($7D_{16}$);
- octet sequence ($7D_{16}$), ($7E_{16}$) aborts the frame.

8.4.5.4 Frame check sequence

The frame check sequence (FCS) shall be calculated as specified in IETF RFC 1662 [14].

NOTE: The FCS is calculated before data transparency.

The FCS shall be transmitted as specified in IETF RFC 1662 [14]: Bit 1 of the first octet is the MSB and bit 8 of the second octet is the LSB, i.e., the FCS bits are transmitted reversed from the normal order.

8.4.5.5 Unit addresses

Each unit uses one source and destination address when communicating with upstream units and a separate independent source and destination address when communicating with downstream units. Each address shall have a value between (0_{16}) and (F_{16}). Units shall be addressed in accordance with table 8.5. Address (F_{16}) may only be used as a destination address and shall specify that the message is addressed to all units. Address (0_{16}) is used to address the next attached or adjacent unit.

Table 8.5: Device addresses

Address ($Base_{16}$)	Device
0	Adjacent device
1	LTU
2	NTU
3 - A	Regenerators 1 - 8
B - E	Reserved (D and E not allowed)
F	Broadcast message to all stations
NOTE: The present document is not intended to indicate how many regenerators can or should be supported by a product; only how to identify them if they exist.	

8.4.5.6 Message IDs

Table 8.6 summarizes message ID and expected message lengths. Message IDs are listed as decimal numbers. Messages 0-64 represent request messages. Messages 128-192 represent messages that are sent in response to request messages. Each request message is acknowledged with the corresponding response. Request/Response Message IDs usually differ by an offset of 128.

Table 8.6: Summary of Message IDs

Message ID(decimal)	Message type	Initiating Unit	Reference (subclause)
0	Reserved		
1	Discovery Probe	LTU, NTU*, REG	8.4.5.7.1
2	Inventory Request	LTU, NTU*	8.4.5.7.3
3	Configuration Request – SDSL	LTU	8.4.5.7.5
4	Reserved for Application Interface Configuration		
5	Configuration Request – Loopback Time-Out	LTU, NTU*	8.4.5.7.6
6	Virtual Terminal Connect Request	NTU*, REG*	8.4.5.7.14
7	Virtual Terminal Disconnect Request	NTU*, REG*	8.4.5.7.14
8	Keyboard Data Message	NTU*, REG*	8.4.5.7.15
9	Maintenance Request –System Loopback	LTU, NTU*	8.4.5.7.16
10	Maintenance Request –Element Loopback	LTU, NTU*	8.4.5.7.17
11	Status Request	LTU, NTU*	8.4.5.7.9
12	Full Status Request	LTU, NTU*	8.4.5.7.10
13 - 14	Reserved		
15	Soft Restart/Power back-off Disable Request	LTU	8.4.5.7.19
16 - 63	Reserved (Future)		
64 - 88	Reserved for Line Management Request	Undefined	8.4.5.7.20
89 - 111	Reserved		
112 - 119	Proprietary Message	Undefined	8.4.5.7.21
120	External Message	Undefined	8.4.5.7.22
121	ITU-T Recommendation G.997.1 [8] Message	LTU*, NTU*	8.4.5.7.23
121 - 124	Reserved		
125 - 127	Excluded ($7D_{16}$, $7E_{16}$, $7F_{16}$)		
128	Reserved		
129	Discovery Response	all	8.4.5.7.2
130	Inventory Response	all	8.4.5.7.4
131	Configuration Response - SDSL	NTU, REG	8.4.5.7.7
132	Reserved for Application Interface Configuration		
133	Configuration Response - Loopback Time-Out	all	8.4.5.7.8
134	Virtual Terminal Connect Response	LTU, REG*, NTU*	8.4.5.7.14
135	Reserved		
136	Screen Data Message	LTU, REG*, NTU*	8.4.5.7.15
137	Maintenance Status	all	8.4.5.7.18
138	Reserved		
139	Status/SNR	all	8.4.5.7.11
140	Performance Status SDSL Network Side	REG, NTU	8.4.5.7.12
141	Performance Status SDSL Customer Side	LTU, REG	8.4.5.7.13
142	Reserved for Application Interface Performance		
143 - 191	Reserved (Future)		
192 - 216	Segment Management Response (reserved)	Undefined	8.4.5.7.20
217 - 247	Reserved (Future)		
240 - 248	Proprietary Message Response	Undefined	8.4.5.7.2
248 - 252	Reserved		
253 - 255	Excluded (FD_{16}, FE_{16}, FF_{16})		
NOTE: *denotes optional support. A unit may initiate this message.			

8.4.5.7 Message contents

Each message shall have the contents in the format specified in table 8.4 through table 8.6. If any message has a message length longer than expected and is received in a frame with a valid FCS, then the known portion of the message shall be used and the extra octets discarded. This will permit addition of new fields to existing messages and maintain backward compatibility. New data fields shall only be placed in reserved bits after the last previously defined data octet. Reserved bits and octets shall be filled with the value (00_{16}) for forward compatibility.

Response messages may indicate UTC (Unable to Comply).

NOTE: This is not in indication of non-compliance. UTC indicates that the responding unit was unable to implement the request.

8.4.5.7.1 Discovery Probe – Message ID 1

The Discovery Probe message shall be assigned Message ID 1, and is used to allow a LTU or NTU to determine how many devices are present and assign addresses to those units.

Table 8.7: Discovery Probe Information Field

Octet #	Contents	Data type	Reference
1	1	Message ID	
2	Hop count	unsigned character	subclause 8.4.3

8.4.5.7.2 Discovery Response – Message ID 129

The Discovery Response message shall be assigned Message ID 129. This message shall be sent in response to a Discovery Probe Message. The Hop Count field shall be set to 1 larger than the value received in the Discovery Probe Message causing the response (the Full Receive State Machine is described in table 8.6). Forward LOSW indication means that the segment is down in the forward direction from the REG. In this case, the REG is unable to forward the Discovery Probe message to the adjacent unit and it reports this fact to the initiating LTU or NTU. The Forward LOSW octet field shall be set to (00_{16}) for responses from a LTU or NTU.

Table 8.8: Discovery Response Information Field

Octet #	Contents	Data Type	Reference
1	129	Message ID	
2	Hop count	unsigned character	8.4.3
3 bits 7..4	Reserved		
3 bits 3..0 - 11	Vendor ID		
12	Vendor eoc Software Version	unsigned character	
13	SDSL version #	unsigned character	
14 bits 7..1	Reserved		
14 bit 0	Forward LOSW indication, eoc unavailable	bit	1 = Unavailable 0 = Available

8.4.5.7.3 Inventory Request – Message ID 2

The Inventory Request message shall be assigned Message ID 2. This message is used to request an Inventory Response from a particular unit. It shall only be transmitted by LTU or NTU devices. There shall be no octets of content for this message.

Table 8.9: Inventory Request Information Field

Octet #	Contents	Data type	Reference
1	2	Message ID	

8.4.5.7.4 Inventory Response – Message ID 130

The Inventory Response message shall be assigned Message ID 130. This message shall be sent in response to an Inventory Request message.

Table 8.10: Inventory Response Information Field

Octet #	Contents	Data type	Reference
1	130	Message ID	
2	SDSL version #	unsigned character	
3 - 5	Vendor list #	3 octet string	
6 - 7	Vendor issue #	2 octet string	
8 - 13	Vendor software version	6 octet string	
14 - 23	Unit identification code	10 octet string	
24 bits 7..4	Reserved		
24 bits 3..0 - 32	Vendor ID (ordered identically to bits TBD:TBD in table TBD)		
33 - 44	Vendor model #	12 octet string	
45 - 56	Vendor serial #	12 octet string	
57 - 68	Other vendor information	12 octet string	

8.4.5.7.5 Configuration Request – SDSL - Message ID 3

The Configuration Request – SDSL message is transmitted by the LTU to configure the SDSL interface(s) of attached units. This message may be broadcast or addressed to specific units. It is acknowledged with a Configuration Response - SDSL message. The content of the information field is shown in table 8.11. Note that the algorithm for calculation of BER is vendor dependent since FEC is vendor dependent. Vendors are responsible for calibrating their units BER for the particular FEC encoder/decoder used. SNR margin is defined as the number of dB above a reference level where 10^{-7} BER is achieved. For SDSL, SNR is measured at the transceiver decision device as opposed to the segment termination. The "Off" setting indicates that threshold crossings are not reported. SDSL Loop Attenuation shall be defined as follows:

$$LoopAtten_{SHDSL}(H) = \frac{2}{f_{Baud}} \left(\int_0^{\frac{f_{Baud}}{2}} 10 * \log_{10}\left[\sum_{n=0}^{1} S(f - nf_{Baud})\right] df - \int_0^{\frac{f_{Baud}}{2}} 10 * \log_{10}\left[\sum_{n=0}^{1} S(f - nf_{Baud}) \left|H(f - nf_{Baud})\right|^2\right] df \right)$$

where f_{Baud} is the symbol rate, $1/H(f)$ is the insertion loss of the loop, and $S(f)$ is the nominal transmit PSD (PSD mask – 1 dB – N), where N denotes the power back-off.

Table 8.11: Configuration Request – SDSL Information Field

Octet #	Contents	Data type	Definition
1	3	Message ID	
2	SDSL Loop attenuation threshold (dB)	character	(00_{16}) – off
3 bits 7..4	SDSL SNR margin threshold (dB)	enumerated	0-off, 1 to 15
3 bits 3..0	SDSL BER threshold	enumerated	0-off, $10^{-1}..10^{-15}$
4	SDSL ES 15 min threshold	character	(00_{16}) – off
5 – 6	SDSL ES 24 hr threshold	16 bit unsigned integer	(00_{16}) – off
7	SDSL SES 15 min threshold	character	(00_{16}) – off
8 – 9	SDSL SES 24 hr threshold	16 bit unsigned integer	(00_{16}) – off
10	SDSL UAS 15 min threshold	character	(00_{16}) – off
11 – 12	SDSL UAS 24 hr threshold	16 bit unsigned integer	(00_{16}) – off

8.4.5.7.6 Configuration Request – Loopback Time-Out - Message ID 5

The Configuration Request – Loopback Time-Out message is transmitted by the LTU (and optionally the NTU) to set loopback time-outs for individual elements. This message may be broadcast or addressed to specific units. It is acknowledged with a Configure response - Loopback Time-Out message.

Table 8.12: Configuration Request – Loopback Time-Out Information Field

Octet #	Contents	Data type	Definition
1	5	Message ID	
2 - 3	Loopback time-out	16-bit unsigned integer	In minutes, ($00_{16}00_{16}$) = no timeout

8.4.5.7.7 Configuration Response – SDSL - Message ID 131

The Configuration Response - SDSL message with the content as defined in table 8.13 is transmitted to the LTU in response to a Configuration Request – SDSL message. This response is sent after the applicable configuration changes have been made. The values of the response shall be set to the new values, after they have been applied. If a transceiver unit is unable to comply (UTC) with the request, the bit in the compliance octet is set and the current settings are reported.

Table 8.13: Configuration Response – SDSL Information Field

Octet #	Contents	Data type	Definition
1	131	Message ID	
2 bits 7..1	Reserved		
2 bit 0	UTC (Unable to Comply)	bit	0 – OK, 1 - UTC
3	SDSL Loop attenuation threshold (dB)	character	(0_{16}) – off
4 bits 7..4	SDSL SNR margin threshold (dB)	enumerated	(0_{16}) - off, 1 to 15
4 bits 3..0	SDSL BER threshold	enumerated	(0_{16}) - off, 10^{-1}..10^{-15}
5	SDSL ES 15 min threshold	character	0 – off
6 - 7	SDSL ES 24 hr threshold	16 bit unsigned integer	0 – off
8	SDSL SES 15 min threshold	character	0 – off
9 - 10	SDSL SES 24 hr threshold	16 bit unsigned integer	0 – off
11	SDSL UAS 15 min threshold	character	0 – off
12 – 13	SDSL UAS 24 hr threshold	16 bit unsigned integer	0 – off

8.4.5.7.8 Configuration Response – Loopback Time-Out - Message ID 133

The Configuration Response – Loopback Time-Out message is transmitted to acknowledge the Configuration Request - applicable configuration changes have been made. The values of the response shall be set to the new values, after they have been applied. If a transceiver unit is unable to comply with the request, the UTC-bit in the compliance octet is set and the current settings are reported.

Table 8.14: System Loopback Time-Out Response Information Field

Octet #	Information field	Data type	Definition
1	133	Message ID	
2	UTC (unable to comply)		0 – OK, 1 UTC
3 - 4	Loopback time-out	16-bit unsigned integer	In minutes, 0 = no timeout

8.4.5.7.9 Status Request – Message ID 11

The Status Request message is used to poll an element for alarm and general performance status.

The relevant status response messages are:

- status/SNR Response – 139 (subclause 8.4.5.7.11);
- SDSL Network Side Performance Status – 140 (subclause 8.4.5.7.12);
- SDSL Customer Side Performance Status – 141 (subclause 8.4.5.7.13);
- maintenance Status – 137 (subclause 8.4.5.7.18).

If no active alarm, fault or maintenance conditions exist and there is no change in any of the values of the performance monitoring fields then the polled unit shall respond with the Status/SNR Response – 139 (subclause 8.4.5.7.11). If no active alarm, fault or maintenance conditions exist and the only change in any of the values of the performance monitoring fields is in the SNR margin then the polled unit shall respond with the Status/SNR Response - 139 (subclause 8.4.5.7.11).

If active alarm, fault or maintenance conditions exist then the polled unit shall respond with the messages that correspond to the active conditions.

If there has been any change in performance status other than SNR margin since the last time a unit was polled then the unit shall respond with the messages which contain the change in performance status.

Table 8.15: Status Request Information Field

Octet #	Information field	Data type
1	Message ID - 11	Message ID

8.4.5.7.10 Full Status Request – Message ID 12

The Full Status Request message is used to poll an element for its complete current status. The following messages shall be sent in response to the Full Status Request:

- SDSL Network Side Performance Status (subclause 8.4.5.7.12);
- SDSL Customer Side Performance Status (subclause 8.4.5.7.13);
- maintenance Status (subclause 8.4.5.7).

Table 8.16: Full Status Request Information Field

Octet #	Information Field	Data Type
1	Message ID - 12	Message ID

8.4.5.7.11 Status Response/SNR – Message ID 139

The Performance Status OK/SNR message shall be sent in response to the Status Request message under the conditions specified in subclause 8.4.5.7.9. The reported integer represents dB SNR noise margin values rounded up. Because each LTU or NTU only connects to one SDSL segment, the application interface side SNR margin data shall be 0. (The network side SNR margin shall be 0 at the LTU and the customer side SNR margin shall be 0 at the NTU).

Table 8.17: Status Response OK/SNR Information Field

Octet #	Information field	Data type
1	Message ID - 139	Message ID
2	Network side SNR margin (dB)	signed character
3	Customer side SNR margin (dB)	signed character

8.4.5.7.12 SDSL Network Side Performance Status – Message ID 140

This message provides the SDSL network side performance status. Device Fault shall be used to indicate HW or SW problems on the addressed unit. The definition of Device Fault is vendor dependent but is intended to indicate diagnostic or self-test results. DC Continuity Fault shall be used to indicate conditions that interfere with span powering such as short and open circuits. The definition of DC Continuity Fault is vendor dependent.

Table 8.18: SDSL-Network Side Performance Status Information Field

Octet #	Contents	Data type	Definition
1	Message ID - 140	Message ID	
2 bit 7..6	reserved		
2 bit 5	Device Fault	bit	0-OK, 1-Fault
2 bit 4	N - DC Continuity Fault	bit	0-OK, 1-Fault
2 bit 3	N - SNR alarm	bit	0-OK, 1-alarm
2 bit 2	N - Loop attenuation alarm	bit	0-OK, 1-alarm
2 bit 1	N - SDSL LOSW failure alarm	bit	0-OK, 1-alarm
2 bit 0	N - SDSL BER alarm	bit	0-OK, 1-alarm
3	N - SDSL SNR margin (dB)	signed character	
4	N - SDSL Loop attenuation (dB)	signed character	
5	N - SDSL ES count modulo 256	unsigned character	
6	N - SDSL SES count modulo 256	unsigned character	
7 - 8	N - SDSL CRC anomaly modulo 64K	unsigned integer	
9	N – SDSL LOSW Defect second count modulo 256	unsigned character	
10	N - Power back-off value (dB)	unsigned character	

8.4.5.7.13 SDSL Customer Side Performance Status – Message ID 141

This message provides the SDSL customer side performance status. Device Fault shall be used to indicate HW or SW problems on the addressed unit. The definition of Device Fault is vendor dependent but is intended to indicate diagnostic or self-test results. DC Continuity Fault shall be used to indicate conditions that interfere with span powering such as short and open circuits. The definition of DC Continuity Fault is vendor dependent.

Table 8.19: SDSL-Customer Side Performance Status Information Field

Octet #	Contents	Data type	Definition
1	Message ID - 141	Message ID	
2 bit 7..6	reserved		
2 bit 5	Device Fault	bit	0-OK, 1-Fault
2 bit 4	C - DC Continuity Fault	bit	0-OK, 1-Fault
2 bit 3	C - SNR alarm	bit	0-OK, 1-alarm
2 bit 2	C - Loop attenuation alarm	bit	0-OK, 1-alarm
2 bit 1	C - SDSL LOSW failure alarm	bit	0-OK, 1-alarm
2 bit 0	C - SDSL BER alarm	bit	0-OK, 1-alarm
3	C - SDSL SNR margin (dB)	signed character	
4	C - SDSL Loop attenuation (dB)	signed character	
5	C - SDSL ES count modulo 256	unsigned character	
6	C - SDSL SES count modulo 256	unsigned character	
7 - 8	C - SDSL CRC anomaly modulo 64K	unsigned integer	
9	C - SDSL LOSW Defect second count modulo 256	unsigned character	
10	C - Power back-off value (dB)	unsigned character	

8.4.5.7.14 Virtual Terminal Connect/Disconnect Request/Response - Message IDs 6,7,134

Three messages are used to maintain (establish, tear down) virtual terminal sessions between units. A unit may request a connection but shall wait for "connect" status response before using the connection. The connection shall remain until a disconnect request is processed or, if implemented, a timeout occurs. At least one session shall be supported by the LTU. NTU and REG may silently ignore the connect request or may respond with a "no connect" status if terminal screens are not supported.

The connect/disconnect process is necessary for handling the case where keyboard messages are received from more than one device. If a unit cannot accommodate another connect request it shall send the "no connect" response.

The connect request message can be sent to cause a refresh of the current screen. When a connect request is accepted the "connect" response shall be transmitted, followed by screen messages with the current screen. If this is a new connection then the first screen shall be sent.

Table 8.20: Virtual Terminal Connect

Octet #	Contents	Data type	Reference
1	Message ID - 6 – Virtual Terminal Connect	Message ID	

Table 8.21: Virtual Terminal Disconnect

Octet #	Contents	Data type	Reference
1	Message ID - 7 – Virtual Terminal Disconnect	Message ID	

Table 8.22: Virtual Terminal Connect Response

Octet #	Contents	Data type	Definition
1	Message ID – 134 - Virtual Terminal Connect response	Message ID	
2	Connection status		1 - connected 0 - no connect

8.4.5.7.15 Screen Message / Keyboard Message - Message IDs 8,136

Keyboard and screen messages are only sent over an active connection between units. Keyboard messages shall be 1 to 8 data octets per message. Queuing of keystrokes from the customer may affect user response times and should be done with care. Screen messages shall be 1 to 24 data octets per message. See subclause 8.4.6 for more information on Screen / Keyboard messages.

Table 8.23: Keyboard Information Field

Octet #	Contents	Data type	Reference
1	Message ID - 8 - Keyboard	Message ID	
Octet. 2 - L + 1	ASCII character(s) and escape sequences	character array	

Table 8.24: Screen Information Field

Octet #	Contents	Data type	Reference
1	Message ID - 136 - Screen	Message ID	
Octet. 2 - L + 1	ASCII characters and escape sequences	character array	

8.4.5.7.16 Maintenance Request – System Loopback - Message ID 9

The Maintenance Request-System Loopback message contains loopback commands for all of the elements on the span. The contents of the Maintenance Request-System Loopback message are shown in table 8.25. The System Loopback message shall have a broadcast destination address when sent from the LTU. When optionally sent from the NTU, the System Loopback message shall have the LTU as its destination address. Upon reception of this message, each REG and LTU or NTU shall comply with its corresponding command field and respond to the sender with the Maintenance Status message. Note that the REGs are numbered consecutively beginning with closest REG to the LTU. Each REG shall determine its number by subtracting 2 from its network side eoc address. Since the network side eoc addresses shall be known, the NTU shall not use the System Loopback Message if the LTU is offline. To invoke REG loopbacks while the LTU is offline, the NTU shall use the Maintenance Request-Element Loopback message. (Maintenance request messages may also be used by the LTU or NTU devices to poll for current loopback status, using the unchanged bit flags.).

Table 8.25: Maintenance Request – System Loopback Information Field

Octet #	Contents	Data type	Reference
Octet 1	Message ID – 9 – Maintenance Request-System Loopback		
Octet 2	LTU Loopback commands	Bit flags	table 8.26
Octet 3	NTU Loopback commands	Bit flags	table 8.26
Octet 4	REG #1 Loopback commands	Bit flags	table 8.26
Octet 5	REG #2 Loopback commands	Bit flags	table 8.26
Octet 6	REG #3 Loopback commands	Bit flags	table 8.26
Octet 7	REG #4 Loopback commands	Bit flags	table 8.26
Octet 8	REG #5 Loopback commands	Bit flags	table 8.26
Octet 9	REG #6 Loopback commands	Bit flags	table 8.26
Octet 10	REG #7 Loopback commands	Bit flags	table 8.26
Octet 11	REG #8 Loopback commands	Bit flags	table 8.26

Table 8.26: Loopback Command Bit Flag Definitions

Bit positions	Definition
Bit 7	Reserved
Bit 6	Clear all maintenance states (including any proprietary states)
Bit 5	Initiate special loopback
Bit 4	Terminate special loopback
Bit 3	Initiate loopback toward the network
Bit 2	Initiate loopback toward the customer
Bit 1	Terminate loopback toward the network
Bit 0	Terminate loopback toward the customer
NOTE: Bit set to 1 – perform action; bit Set to 0 - no action taken, report current status.	

8.4.5.7.17 Maintenance Request – Element Loopback - Message ID 10

The Maintenance Request-Element Loopback message contains loopback commands for an individual element. The contents of the Maintenance Request-Element Loopback message are shown in table 8.27. The Element Loopback message shall have an individual unit's destination address according to the data flow addresses described in subclause 8.4.2. Upon reception of the Element Loopback message, the addressed unit shall comply with the loopback commands and reply with the Maintenance Status Response message.

Table 8.27: Maintenance Request – Element Loopback Information Field

Octet #	Contents	Data type	Reference
1	Message ID - 10 - Maintenance Request	Message ID	
2	Loopback commands	Bit flags	table 8.26

8.4.5.7.18 Maintenance Status Response - Message ID 137

Maintenance status is sent in response to the Maintenance Request-System Loopback and the Maintenance Request-Element Loopback Query messages. The "Special Loopback" is defined for the NTU as a Maintenance Termination Unit (MTU) Loopback; it is not defined at other units.

Table 8.28: Maintenance Status Information Field

Octet #	Contents	Data type	Definition
1	Message ID - 137 – Maintenance Status-Loopback	Message ID	
2 bit 7	Reserved		
2 bit 6	Proprietary Maintenance State active	bit	0-off, 1-on
2 bit 5	Special loopback active	bit	0-off, 1-on
2 bit 4	Loopback active toward NTU	bit	0-off, 1-on
2 bit 3	Loopback active toward LTU	bit	0-off, 1-on
2 bit 2	Local or span-powered unit	bit	0 = span powered 1 = local powered
2 bit 1	Customer Tip/Ring reversal	bit	0 = normal 1 = reversed
2 bit 0	Network Tip/Ring reversal	bit	0 = normal 1 = reversed

8.4.5.7.19 Soft Restart/Power Back-off Disable Message - Message ID 15

The purpose of this message is to disable or enable the power back-off mode on a unit and/or restart the segment. The Soft Restart message shall cause the receiving unit to terminate the SDSL connection and enter the Exception State. The connection shall not be terminated unless the Soft Restart bit is set in this message. The receiving unit shall wait 5 ± 1 seconds before terminating the SDSL connection.

This message carries the command to set the power back-off mode. The power back-off mode received in this message shall be maintained as long as power is applied to the unit. Maintaining the power back-off mode in non-volatile storage is optional.

Table 8.29: Soft Restart Information Field

Octet #	Contents	Data type	Definition
1	Message ID - 15 - Soft Restart/Back-off	Message ID	
2 Bits 7..2	Reserved		
2 Bit 1	Power Back-off disable/enable (All sides – customer and/or network)	bit	1 = disable 0 = enable
2 Bit 0	Soft Restart (after 5 seconds)	bit	1 = restart 0 = no restart

8.4.5.7.20 Segment Management Message - Message IDs 64 - 88, 192 - 216

A range of Message IDs is reserved for segment management (e.g. continuous precoder update).

8.4.5.7.21 Proprietary Messages - Message IDs 112 - 119, 240 - 247

A range of Message IDs is reserved for proprietary messages. It is the responsibility of the LTU or NTU to address Proprietary Messages to the appropriate destination. An REG shall either process or forward a proprietary message. A proprietary message shall not be broadcast.

8.4.5.7.22 Proprietary External Message - Message ID 120

Support for external data ports is optional. No interface for an external data port is specified in the present document. If an LTU or NTU does not have an external data port then it shall ignore any received Proprietary External Messages.

Table 8.30: External Information Field

Octet #	Contents	Data type	Reference
1	Message ID - 120 - external	Message ID	
2	Logical Port Number	Unsigned character	
Octets 3 .. L + 2	External message data		

8.4.5.7.23 G.997.1 External Message - Message ID 121

Support for ITU-T Recommendation G.997.1 [8] external messaging is optional. The interface for ITU-T Recommendation G.997.1 [8] messages is beyond the scope of the present document. If an LTU or NTU does not have an interface for ITU-T Recommendation G.997.1 [8] messaging, it shall ignore any received ITU-T Recommendation G.997.1 [8] External Messages.

Table 8.31: ITU-T Recommendation G.997.1 [8] External Information Field

Octet #	Contents	Data type	Reference
1	Message ID - 121	Message ID	
2	Logical Port Number	Unsigned character	
octets 3 .. L + 2	ITU-T Recommendation G.997.1 [8] External message data		

8.4.6 Examples of Virtual Terminal Control Functions

This informative note gives examples of some common ANSI X3.4 (R1997) [15] escape sequences.

Table 8.32: Examples of ANSI X3.4 (R1997) [15] Control Functions

Description	Format	Comments
Erase entire screen (ED)	ESC [2 J]	
Position cursor (CUP)	ESC [RR;CCH]	See NOTE
Position cursor (in column 1)	ESC [RRH]	subset of position cursor
Home cursor	ESC [H]	subset of position cursor
NOTE: ESC has the value of $1B_{16}$. RR is the row number; CC is the column number expressed as ASCII digits. As an example, row 4 column 12 would encode as ESC [4;12H. The hexadecimal equivalent of this sequence is $1B_{16}$ $5B_{16}$ 34_{16} $3B_{16}$ 31_{16} 32_{16} 48_{16}. The screen starts with row 1, column 1.		

9 Electrical characteristics of a SDSL transceiver

9.1 General

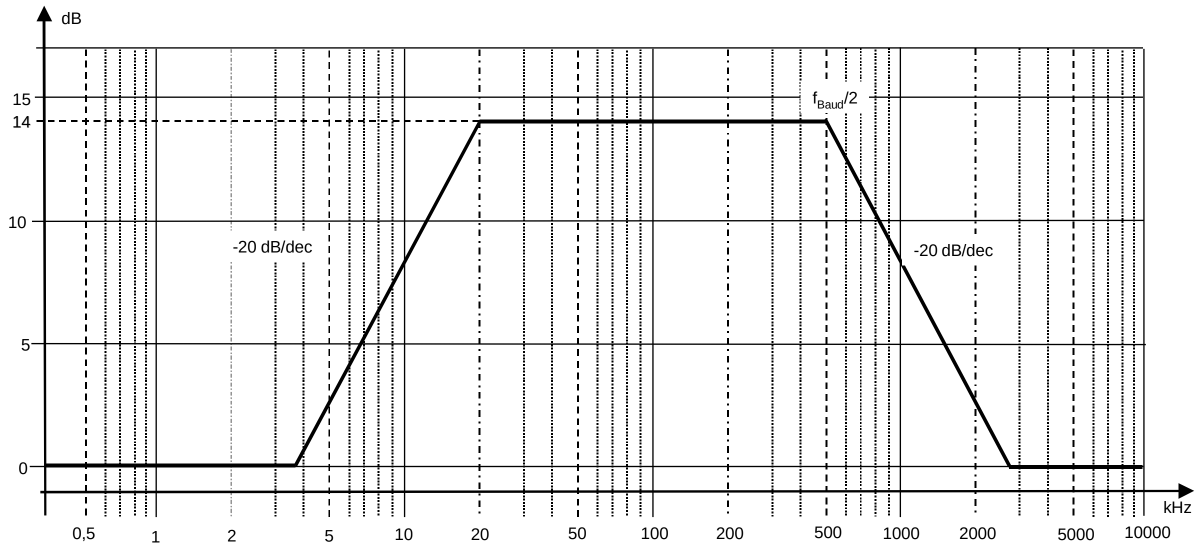
This subclause describes the electrical characteristics of an SDSL transceiver.

The electrical characteristics of an SDSL transceiver shall be such as to enable the performance requirements of appropriate applications, which are described in application dependent annexes, to be met. In addition, the following specific electrical line characteristics are required.

9.2 Transmitter/Receiver impedance and return loss

The nominal driving point impedance at the line side of an SDSL transceiver shall be 135 Ω. The minimum return loss with respect to 135 Ω over a frequency band of 1 kHz to 1 MHz shall be:

- 14 dB from 20 kHz to $f_{Baud}/2$ kHz as shown in figure 9.1 for a 1 000 kBaud system with a slope of 20 dB/decade below respectively above these frequencies.



NOTE: It is expected that the above specification of return loss will be replaced by a specification of another electrical characteristic that is more appropriate and will probably be a frequency dependent output impedance.
This enables a prediction of signal levels on real cables from signal level measurements under different impedance conditions.

Figure 9.1: Minimum return loss of a 1 000 kBaud system

9.3 Unbalance about earth

9.3.1 Longitudinal conversion loss

The longitudinal conversion loss is given by: $LCL = 20 \log (e_l/e_m)$ [dB]:

- where e_l is the applied longitudinal voltage referenced to the building ground and em is the resultant metallic voltage appearing across a 135 Ω termination.

The longitudinal conversion loss of the system shall meet the requirement of: 40 dB between 5 kHz and $f_{Baud}/2$ kHz as shown in figure 9.2 for a 1 000 kBaud system, with a slope of 20 dB/decade below respectively above these frequencies. This requirement ensures that the overall LCL is not significantly worse than that of the DLLs alone.

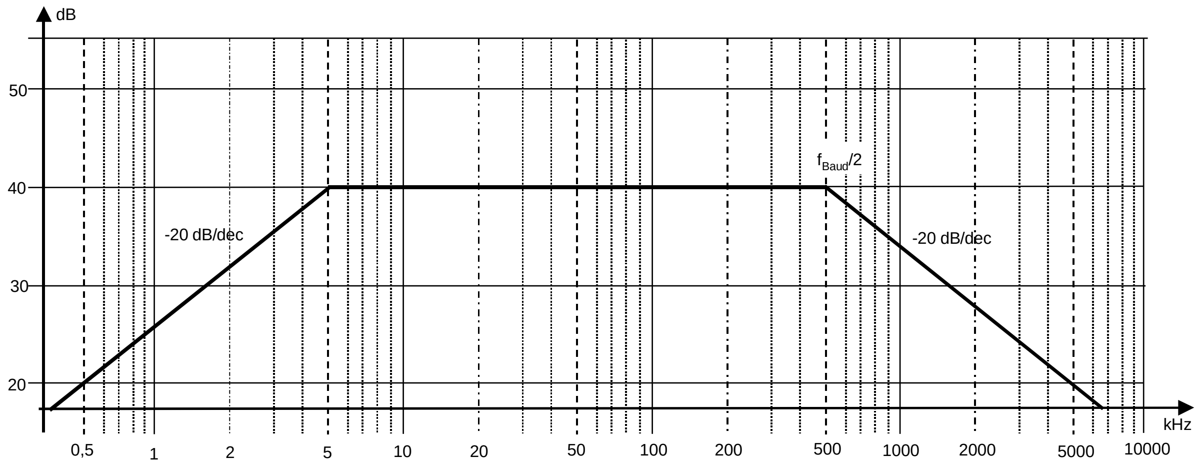
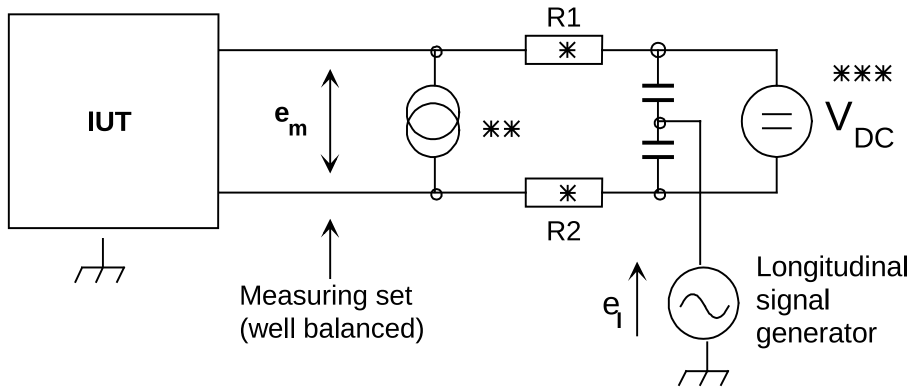


Figure 9.2: Minimum longitudinal conversion loss for a 1 000 kbaud system

Figure 9.3 defines a measurement method for longitudinal conversion loss. For direct use of this configuration, measurement should be performed with the IUT powered up but inactive (no transmitted signal; driving 0 V).



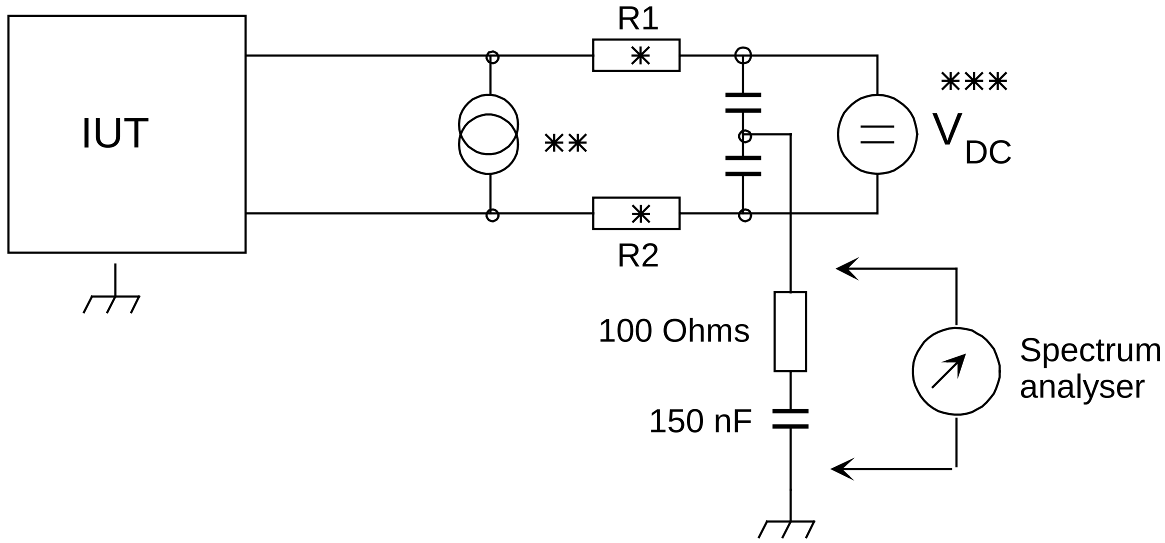
NOTE 1: *These resistors have to be matched: R1 = R2 = 135/2 Ω and R1/R2 = 1 ± 0,1 %.
NOTE 2: **For LTU test only if remote power feeding is supplied.
NOTE 3: ***For NTU test only if remote power feeding is required.
NOTE 4: During regenerator test (where required) each wire on the side which is not under test has to be connected to ground by a terminating impedance having the value of 135/2 Ω in series with a capacitance of 0,33 µF.

Figure 9.3: Measurement method for longitudinal conversion loss

9.3.2 Longitudinal output voltage

The longitudinal component of the output signal shall have an rms voltage, in any 4 kHz equivalent bandwidth averaged in any second period, < -50 dBV over the frequency range 100 Hz to 400 kHz. Compliance with this limitation is required with a longitudinal termination having an impedance of 100 Ω in series with 0,15 µF nominal. The EMC requirements of subclause 12.4 shall also be met.

Figure 9.4 defines a measurement method for longitudinal output voltage. For direct use of this test configuration, the IUT should be able to generate a signal in the absence of a signal from the far end. The ground reference for these measurements shall be the building ground.



NOTE1: *These resistors have to be matched: R1 = R2 = 135/2 Ω and R1/R2 = 1 ± 0,1 %.
NOTE 2: **For LTU test only if remote power feeding is supplied.
NOTE 3: ***For NTU test only if remote power feeding is required.
NOTE 4: During regenerator test (where required) each wire on the side which is not under test has to be connected to ground by a terminating impedance having the value of 135/2 Ω in series with a capacitance of 0,33 µF.

Figure 9.4: Measurement method for longitudinal output voltage

9.4 Signal transfer delay

The one way signal transfer delay between the application interfaces at customer and network side calculated as the mean value for both directions shall be including an regenerator:

- ≤1 250 µs for narrowband services;
- ≤5 000 µs for broadband data.

10 Laboratory performance measurements

10.1 General

The purpose of transmission performance tests is to stress SDSL transceivers in a way that is representative to a high penetration of systems scenario in operational access networks. This high penetration approach enables operators to define deployment rules that apply to most operational situations. It means also that in individual operational cases, characterized by lower noise levels and/or insertion loss values, the SDSL system under test may perform better than tested.

The performance requirements given in this clause are dedicated to SDSL transceivers, but the concept is upgradable to other systems such as "ADSL over ISDN". The design impedance R_V is 135 Ω. All spectra are representing single sided power spectral densities (PSD).

10.2 Test procedure

The purpose of this subclause is to provide an unambiguous specification of the test set-up, the insertion path and the way signal and noise levels are defined. The tests are focused on the noise margin, with respect to the crosstalk noise or impulse noise levels when SDSL signals under test are attenuated by standard test-loops and interfered with standard crosstalk noise or impulse noise. This noise margin indicates what increase of crosstalk noise or impulse noise level is allowed under (country-specific) operational conditions to ensure sufficient transmission quality.

10.2.1 Test set-up definition

Figure 10.1 illustrates the functional description of the test set-up. It includes:

- a bit error ratio test set (BERTS) applies a 2^{15}-1 pseudo random bit sequence (PRBS) test signal to the transmitter in the direction under test at the bitrate required. The transmitter in the opposing direction shall be fed with a similar PRBS signal, although the reconstructed signal in this path need not be monitored;
- the test loops, as specified in subclause 10.4.3;
- an adding element to add the impairment noise (a mix of random, impulsive and harmonic noise), as specified in subclause 10.4.5;
- a high impedance, and well balanced (e.g. better than 60 dB across the whole band of the SDSL system under test) differential voltage probe connected with level detectors such as a spectrum analyser or a true rms voltmeter.

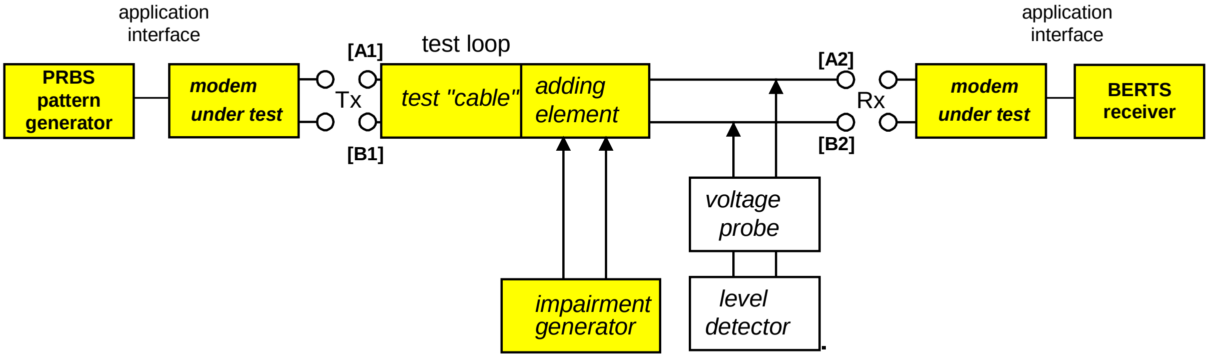


Figure 10.1: Functional description of the set-up of the performance tests

The two-port characteristics (transfer function, impedance) of the test-loop, as specified in subclause 10.4, are defined between port Tx (node pairs A1, B1) and port Rx (node pair A2, B2). The consequence is that the two-port characteristics of the test "cable" in figure 10.1 shall be properly adjusted to take full account of non-zero insertion loss and non-infinite shunt impedance of the adding element and impairment generator. This is to ensure that the insertion of the generated impairment signals does not appreciably loads the line.

The balance about earth, observed at port Tx at port Rx and at the tips of the voltage probe shall exhibit a value that is 10 dB greater than the transceiver under test. This is to ensure that the impairment generator and monitor function does not appreciably deteriorate the balance about earth of the transceiver under test.

The signal flow through the test set-up is from port Tx to port Rx, which means that measuring upstream and downstream performance requires an interchange of transceiver position and test "cable" ends.

The received signal level at port Rx is the level, measured between node A2 and B2, when port Tx as well as port Rx are terminated with the SDSL transceivers under test. The impairment generator is switched off during this measurement.

Test Loop #0, as specified in subclause 10.4, shall always be used for calibrating and verifying the correct settings of generators G1-G7, as specified in subclause 10.4.5, when performing performance tests.

The transmitted signal level at port Tx is the level, measured between node A1 and B1, under the same conditions.

The impairment noise shall be a mix of random, impulsive and harmonic noise, as defined in subclause 10.4.5. The level that is specified in subclause 10.4.5 is the level at port Rx, measured between node A2 and B2, while port Tx as well as port Rx are terminated with the design impedance R_V. These impedances shall be passive when the transceiver impedance in the switched-off mode is different from this value.

10.2.2 Signal and noise level definitions

The signal and noise levels are probed with a well balanced differential voltage probe, and the differential impedance between the tips of that probe shall be higher than the shunt impedance of 100 kΩ in parallel with 10 pF. Figure 10.1 shows the probe position when measuring the Rx signal level at the LT or NT receiver. Measuring the Tx signal level requires the connection of the tips to node pair [A1, B1].

NOTE: The various levels (or spectral masks) of signal and noise that are specified in the present document are defined at the Tx or Rx side of this set-up. The various levels are defined while the set-up is terminated, as described above, with design impedance R_V or with SDSL transceivers under test.

Probing an rms-voltage U_{rms} [V] in this set-up, over the full signal band, means a power level of P [dBm] that equals:

- $P = 10 \times \log_{10}(U_{rms}^2/R_V \times 1\,000)$ [dBm].

Probing an rms-voltage U_{rms} [V] in this set-up, within a small frequency band of Δf [Hz], means an average spectral density level of P [dBm/Hz] within that filtered band that equals:

- $P = 10 \times \log_{10}(U_{rms}^2/R_V \times 1\,000/\Delta f)$ [dBm/Hz];
- the bandwidth Δf identifies the noise bandwidth of the filter, and not the –3dB bandwidth.

10.3 Performance test procedure

The test performance of the SDSL transceiver shall be such that the bit error ratio (BER) on the disturbed system is less than 10^{-7}, while transmitting a pseudo random bit sequence. The BER should be measured after at least 10^9 bits have been transmitted.

The tests are carried out with a margin which indicates what increase of noise is allowed to ensure sufficient transmission quality. Network operators will calculate their own margins for planning purposes based on a knowledge of the relationship between this standard test set and their network characteristics.

A test sequence as specified in table 10.1 shall be concluded. The testloops referred to are specified in figure 10.2. The test loops are characterized by the insertion loss Y and/or the cable length L, which depend on the data rate to be transported and has to be scaled adequately.

Table 10.1: Test sequence for performance testing

N	Test Path	Direction	Comments
1	#1 note 1	Forward	Y = 0 dB; Test noise as defined in clause 10.5
2	#2	Forward	Y = Y1 (note 2); Test noise as defined in clause 10.5
3	#3	Forward	Y = Y1; Test noise as defined in clause 10.5
4	#3	Reverse	Y = Y1; Test noise as defined in clause 10.5
5	#4	Forward	Y = Y1; Test noise as defined in clause 10.5
6	#4	Reverse	Y = Y1; Test noise as defined in clause 10.5
7	#5	Forward	Y = Y1; Test noise as defined in clause 10.5
8	#6	Forward	Y = Y1; Test noise as defined in clause 10.5
9	#6	Reverse	Y = Y1; Test noise as defined in clause 10.5
10	#7	Forward	Y = Y1; Test noise as defined in clause 10.5
11	#7	Reverse	Y = Y1; Test noise as defined in clause 10.5>
12			Common mode rejection test (note 4)
13	note 3	Forward and Reverse	Y = Y2; Test noise as defined in clause 10.5 Worst path of tests 1 to 11
14	note 3	note 3	Y = Y3; No added impairment; Worst path of tests 1 to 11;BER < 10^{-8}
15	#2	Forward	Y = Y1; Impulse test as described in as defined in clause 10.6.2
16	As <TBD>	Forward	Micro interruption test as described in as defined in clause 10.7

NOTE 1: Test Path = #1 means that the path under test shall be connected with test loop #1 as defined in figure 11.2.
NOTE 2: Y1 = as described in Table 10.2: dB, Y2 = Y1 - 10 dB, Y3 = Y1 + 3 dB.
NOTE 3: The tests are carried out on the worst testloop from tests 1 to 11. If there are no errors, then loop #3 forward is taken as default.
NOTE 4: The measuring arrangement for this test is specified in ITU-T Recommendation O.9 [12].

10.4 Test loops

10.4.1 Functional description

The test loops in figure 10.2 are based on the existing HDSL testloops as defined in TS 101 135 [2]. A Technical Specification for unified testloops across all DSL-technologies is currently under development. When the present document becomes available and is judged appropriate for SDSL testing, it will replace the current testloops.

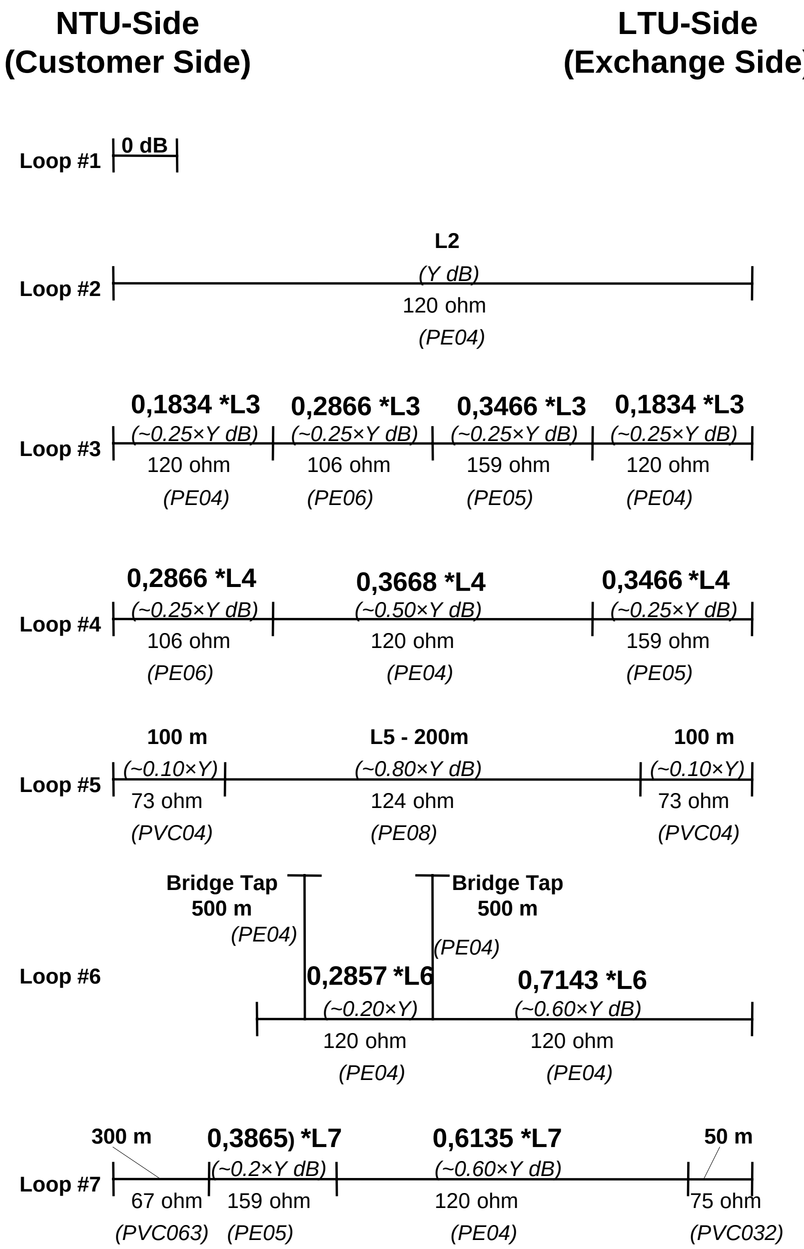
The length of the individual loops are such chosen that the transmission characteristics of all loops are comparable (see figure 10.2). The purpose of this is to stress the equalizer of the SDSL modem under test similarly over all loops, when testing SDSL at a specific bit rate. The total length of each loop is described in terms of *physical* length, and the length of the individual sections as a fixed fraction of this total. If implementation tolerances of one testloop causes that its resulting *electrical* length is out of specification, then its total physical length shall be scaled accordingly to correct this error.

One test loop includes bridged taps to achieve rapid variations in amplitude and phase characteristics of the cable transfer function. In some European access networks, these bridge taps have been implemented in the past, which stresses the SDSL modem under test differently.

Loop #1 is a symbolic name for a loop with zero (or near zero) length, to prove that the SDSL transceiver under test can handle the potentially high signal levels when two transceivers are directly interconnected.

10.4.2 Testloop topology

The topology of the testloops is specified in figure 10.2. The basic test cable characteristics, the transfer function of the testloops specified using these cables and the variation of input impedance of the testloops are shown in annex A.



NOTE 1: The values for Y and L are to be found in table 10.2.

NOTE 2: Due to mismatches and Bridged Taps the total attenuation of the testloops differs from the sum of the attenuation of the parts.

NOTE 3: The impedances are for information only. They refer to the characteristic impedances of the testcables as defined in annex B measured at 300 kHz.

Figure 10.2: Testloop topology

10.4.3 Testloop length

The length of each testloop for SDSL transmission systems is specified in table 10.2. The specified insertion loss Y at the specified test frequency measured with a 135 Ω termination (*electrical* length) is mandatory. If implementation tolerances of one testloop causes that its resulting *electrical* length is out of specification, then its total *physical* length shall be scaled accordingly to adjust this error.

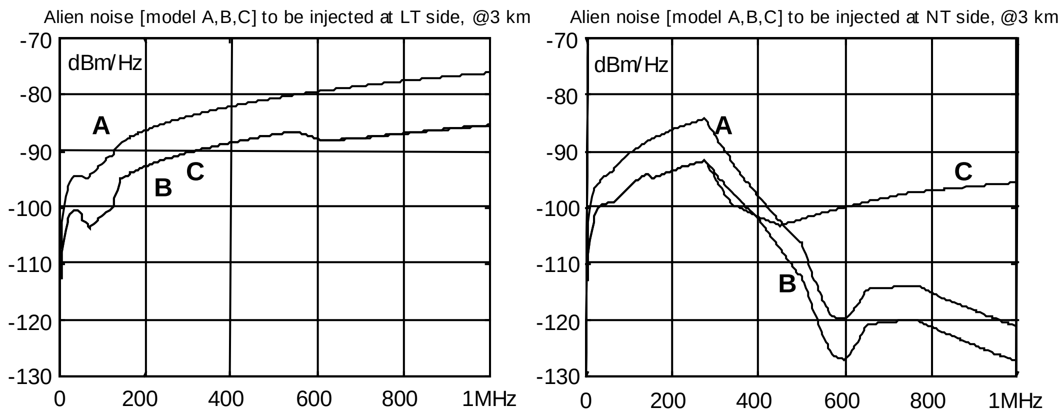
The test frequency f_T is chosen to be a typical mid-band frequency in the spectrum of long range SDSL systems. The length is chosen to be a typical maximum value that can be handled correctly by the SDSL transceiver under test. This value is bit rate dependent; the higher the payload bit rate, the lower is the insertion loss that can be handled in practice.

Table 10.2: Approximation for the physical length of the SDSL testloops, calculated for different electrical lengths

Payload bit rate [kbit/s]	f_T [kHz]	Y [dB] @f_T, @135 Ω	L1 [m]	L2 [m]	L3 [m]	L4 [m]	L5 [m]	L6 [m] = 0.8 - L2	L7 [m]	L8 [m] = L4
384	150	47,13	< 3	4 500 NOTE	6 096,0	6 104,0	12 218,0	3 600,0	5 175,0	6 104,0
512	150	43,56	< 3	4 160	5 635,0	5 641,0	11 221,0	3 328,0	4 767,0	5 641,0
768	150	38,33	< 3	3 662	4 960,7	4 962,0	9 759,7	2 929,6	4 154,7	4 962,0
1 024	150	34,77	< 3	3 323	4 496,5	4 501,8	8 765,7	2 658,4	3 728,0	4 501,8
1 280	150	32,94	< 3	3 148	4 256,8	4 264,1	8 251,9	2 518,4	3 510,4	4 264,1
1 536	150	29,03	< 3	2 776	3 750,4	3 755,0	7 161,2	2 220,8	3 065,3	3 755,0
2 048	150	25,09	< 3	2 400 NOTE	3 229,1	3 235,2	6 059,0	1 920,0	2 626,1	3 235,2
2 304	150	23,75	< 3	2 273	3 055,3	3 061,8	5 683,9	1 818,4	2 475,6	3 061,8
NOTE: This values are goals for loop reach with noise models B, C or D as described in subclause 10.5, which have to be reconsidered with respect to agreements on Power Spectral Density masks. All other values have been calculated under the assumption that these goals can be reached. Values for noise A are under study.										

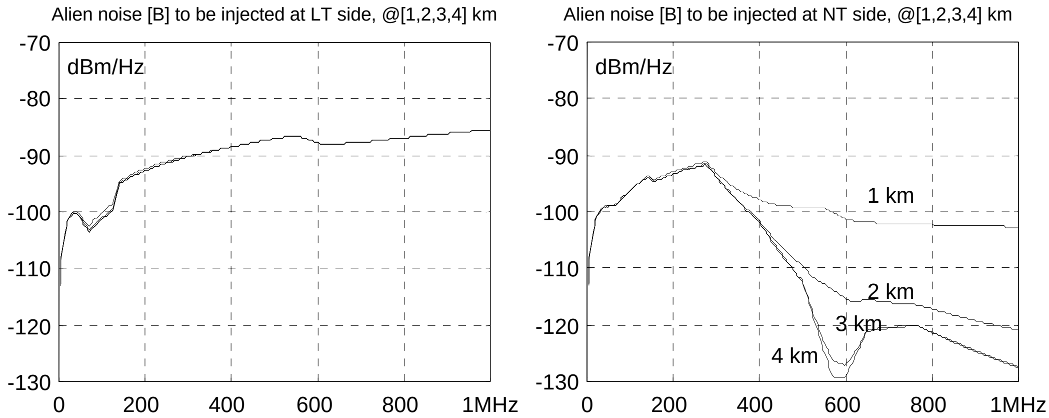
10.5 Impairment generator

The noise that the impairment generator injects into the test set-up is frequency dependent, is dependent on the length of the testloop and is also different for downstream performance tests and upstream performance tests. Figure 10.3 illustrates this for the ***alien*** noise (other then the SDSL modem under test) in the case that the length of testloop #1 is fixed at 3 km. Figure 10.4 illustrates this for various loop lengths in the case that the ***alien*** noise of model 'B' is applied. These figures are restricted to alien noise only, because the PSD of SDSL is for further study. The self noise (of SDSL) shall be combined with this alien noise.



NOTE: This is the noise, resulting from three of the four noise models for SDSL, in the case that the length of testloop #1 is fixed at 3 km.

Figure 10.3: Examples of alien noise spectra that are to be injected into the test set-up, while testing SDSL systems



NOTE: This is the alien noise, resulting from noise model B for SDSL, in the case that the length of testloop #1 varies from 1 km to 4 km. This demonstrates that the test noise is length dependent, to represent the FEXT in real access network cables.

Figure 10.4: Examples of alien noise spectra that are to be injected into the test set-up, while testing SDSL systems

The definition of the impairment noise for SDSL performance tests is very complex and for the purposes of this Technical Specification it has been broken down into smaller, more easily specified components. These separate, and uncorrelated, impairment "generators" may therefore be isolated and summed to form the impairment generator for the SDSL system under test. The detailed specifications for the components of the noise model(s) are given in this subclause, together with a brief explanation.

10.5.1 Functional description

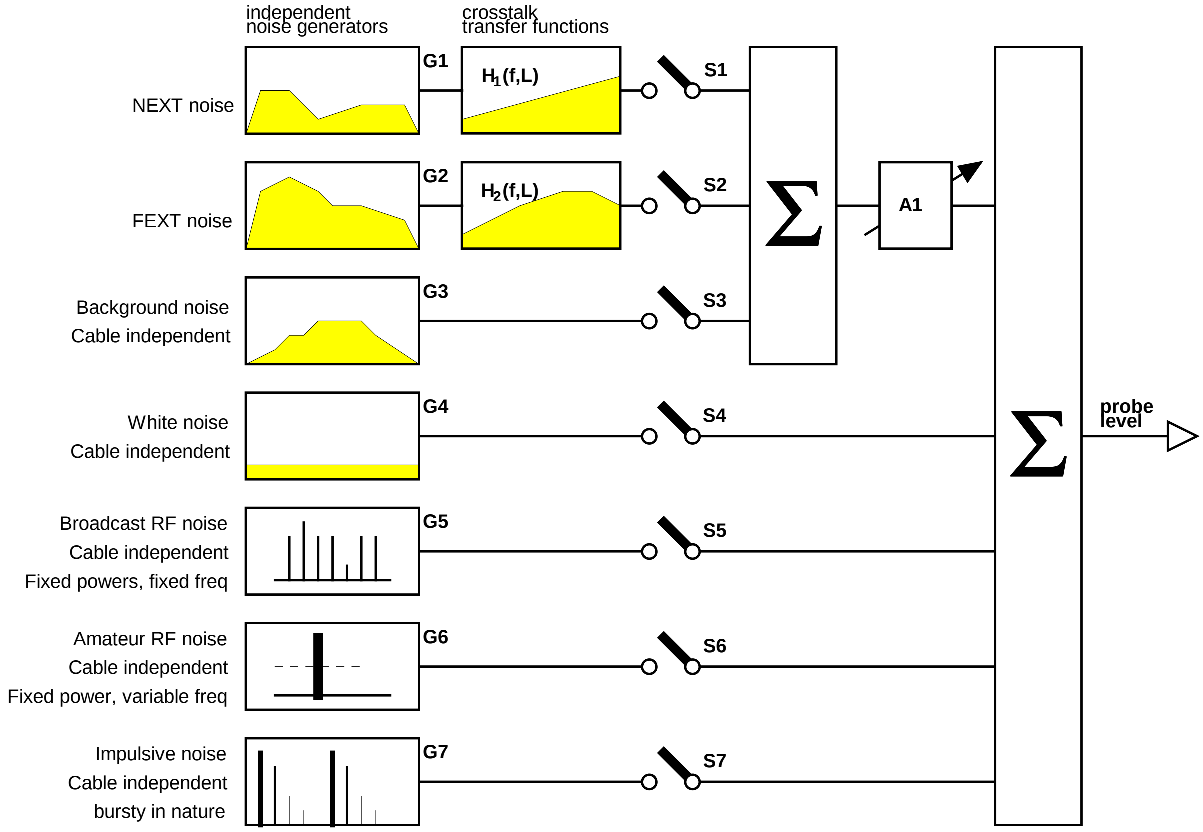
Figure 10.5 defines a functional diagram of the composite impairment noise. It defines a functional description of the combined impairment noise, as it shall be probed at the receiver input of the SDSL transceiver under test. The probing is described in subclause 10.2.2.

The functional diagram has the following elements:

- the seven impairment "generators" G1 to G7 generate noise as defined in subclauses 10.5.3.1 to 10.5.3.7. Their noise characteristics are independent from the testloops and bit rates;
- the transfer function $H_1(f,L)$ models the length and frequency dependency of the NEXT impairment, as specified in subclause 10.5.3.1. The transfer function is independent of the testloops, but changes with the electrical length of the testloop. Its transfer function changes with the frequency *f*, roughly according to $f^{0,75}$;
- the transfer function $H_2(f,L)$ models the length and frequency dependency of the FEXT impairment, as specified in subclause 10.5.3.2. Its transfer function is independent of the testloops number, but changes with the electrical length of the testloop. Its transfer function changes with the frequency *f*, roughly according to *f* times the cable transfer function;
- switches S1-S7 determine whether or not a specific impairment generator contributes to the total impairment during a test;
- amplifier A1 models the property to increase the level of some generators simultaneously to perform the noise margin tests. A value of x dB means a frequency independent increase of the level by x dB over the full band of the SDSL system under test, from f_L to f_H. Unless otherwise specified, its gain is fixed at 0 dB.

In a practical implementation of the test set-up, there is no need to give access to any of the internal signals of the diagram in figure 10.5. These functional blocks may be incorporated with the testloop and the adding element as one integrated construction.

The average transfer function $s_{T0}(\omega,L)$ of the four testloops is the s_{21} transfer function parameter in source/load resistance R_V of testloop #1 at specified payload bit rate. It is considered as an average of all the four loops at equal electrical length (normalized in insertion loss at a specified test frequency).



NOTE 1: Generator G7 is the only one which is symbolically shown in the time domain.
NOTE 2: The precise definition of impulse noise margin is for further study.

Figure 10.5: Functional diagram of the composition of the impairment noise

This functional diagram will be used for impairment tests in downstream and upstream direction. Several scenarios have been identified to be applied to SDSL testing. These scenarios are intended to be representative of the impairments found in metallic access networks.

Each scenario (or noise model) results in a length dependent PSD description of noise. Each noise model is subdivided into two parts: one to be injected at the LT-side, and another to be injected at the NT-side of the SDSL modem link under test. Some of the seven individual impairment "generators" G1 to G7 are therefore defined by more than one noise model.

Each test has its own impairment specification. The overall impairment noise shall be characterized by the sum of the individual components as specified in the relevant subclauses. This combined impairment noise is applied to the receiver under test, at either the LT (for upstream) or NT (for downstream) ends of the testloop.

10.5.2 Cable crosstalk models

The purpose of the cable cross-talk models is to model both the length and frequency dependency of crosstalk measured in real cables. These crosstalk transfer functions adjust the level of the noise generators in figure 10.4 when the electrical length of the testloops is changed. The frequency and length dependency of these functions is in accordance with observations from real cables. The specification is based on the following constants, parameters and functions:

- variable f identifies the frequency in Hz;
- constant f_0 identifies a chosen reference frequency, which was set to 1 MHz;
- variable L identifies an average physical length in meters. This physical length is calculated from the cable models in annex A, from the specified electrical length. Value are summarized in table 2 for each combination of payload bitrate, noise model and test loop;
- constant L_0 identifies a chosen reference length, which was set to 1 km;

- transfer function $s_{T0}(f, L)$ represents the frequency and length dependent amplitude of the transfer function of the actual test loop. This value equals sT=|s21|, where s21 is the transmission s-parameter of the loop normalized to 135 Ω. Annex A provides formula's to calculate this s-parameter;
- constant K_{xn} identifies an empirically obtained number that scales the NEXT transfer function $H_1(f, L)$. The resulting transfer function represents a power summed crosstalk model of the NEXT as it was observed in a test cable. Although several disturbers and wire pairs were used, this function $H_1(f, L)$ is scaled down as if it originates from a single disturber in a single wire pair;
- constant K_{xf} identifies an empirically obtained number that scales the FEXT transfer function $H_2(f, L)$. The resulting transfer function represents a power summed crosstalk model of the FEXT as it was observed in a test cable. Although several disturbers and wire pairs were used, this function $H_2(f, L)$ is scaled down as if it originates from a single disturber in a single wire pair.

The transfer functions in Table10.3 shall be used as crosstalk transfer functions in the impairment generator.

Table 10.3: Definition of the crosstalk transfer functions

$H_1(f, L) = K_{xn} \times (f/f_0)^{0,75} \times \sqrt{1 - \lvert s_{T0}(f, L)\rvert^4}$ $H_2(f, L) = K_{xf} \times (f/f_0) \times \sqrt{(L/L_0)} \times \lvert s_{T0}(f, L)\rvert$
$K_{xn} = 10^{(-50/20)} \approx 0{,}0032$, $f_0 = 1$ MHz $K_{xf} = 10^{(-45/20)} \approx 0{,}0056$, $L_0 = 1$ km $s_{T0}(f, L)$ = averaged test loop transfer function
NOTE: These values are rounded values, and chosen to be close to the ANSI T1E1.4 VDSL draft System Requirements. This choice is equivalent to 50 dB NEXT loss and 45 dB EL-FEXT loss at a cable section of 1 km. At this moment, it is by no means sure that these are reasonable values to represent the 'average' European cables. The few measurements that are available for European cables demonstrate sometimes significant differences from the above values. This is an area of further study.

10.5.3 Individual impairment generators

10.5.3.1 Equivalent NEXT disturbance generator [G1.xx]

The NEXT noise generator represents the equivalent disturbance of all impairment that is identified as crosstalk noise from a predominantly near end origin. This noise, filtered by the NEXT crosstalk coupling function of subclause 10.5.2, will represent the contribution of all NEXT to the composite impairment noise of the test.

The PSD of this noise generator is one of the PSD profiles, as specified in subclause 10.4.4 For testing upstream and downstream performance different PSD profiles shall be used, as specified below.

G1.LT.# = X.LT.#

G1.NT.# = X.NT.#

The symbols in this expression, refer to the following:

- symbol "#" is a placeholder for noise model "A", "B", "C" or "D";
- symbol "X.LT.#" and "X.NT.#" refers to the self crosstalk profiles, as defined in subclause 10.4.4.

This PSD is not related to the cable because the cable portion is modelled separately as transfer function $H_1(f,L)$, as specified in subclause 10.4.2.

The noise of this noise generator shall be uncorrelated with all the other noise sources in the impairment generator, and uncorrelated with the SDSL system under test. The noise shall be random in nature and near Gaussian distributed, as specified in subclause 10.4.4.2.

10.5.3.2 Equivalent FEXT disturbance generator [G2.xx]

The NEXT noise generator represents the equivalent disturbance of all impairment that is identified as crosstalk noise from a predominantly near end origin. This noise, filtered by the NEXT crosstalk coupling function of subclause 10.5.2, will represent the contribution of all NEXT to the composite impairment noise of the test.

The PSD of this noise generator is one of the PSD profiles, as specified in subclause 10.4.4. For testing upstream and downstream performance different PSD profiles shall be used, as specified below.

G2.LT.# = X.NT.#

G2.NT.# = X.LT.#

The symbols in this expression, refer to the following:

- symbol "#" is a placeholder for noise model "A", "B", "C" or "D";
- symbol "X.LT.#" and "X.NT.#" refers to the self crosstalk profiles, as defined in.10.4.4.

This PSD is not related to the cable because the cable portion is modelled separately as transfer function $H_2(f,L)$, as specified in subclause 10.4.2.

The noise of this noise generator shall be uncorrelated with all the other noise sources in the impairment generator, and uncorrelated with the SDSL system under test. The noise shall be random in nature and near Gaussian distributed, as specified in subclause 10.4.4.2.

10.5.3.3 Background noise generator [G3]

The background noise generator is inactive and set to zero.

10.5.3.4 White noise generator [G4]

The white noise generator has a fixed, frequency independent value, and is set to –140dBm/Hz, into 135 Ω. The noise of this noise generator shall be uncorrelated with all the other noise sources in the impairment generator, and uncorrelated with the SDSL system under test. The noise shall be random in nature and near Gaussian distributed, as specified in subclause 10.4.4.2.

10.5.3.5 Broadcast RF noise generator [G5]

The broadcast RF noise generator represents the discrete tone-line interference caused by amplitude modulated broadcast transmissions in the SW, MW and LW bands which ingress into the differential or transmission mode of the wire-pair. These interference sources have more temporal stability than the amateur/ham interference because their carrier is not suppressed. The modulation index (MI) is usually up to 80 %. These signals are detectable using a spectrum analyser and result in line spectra of varying amplitude in the frequency band of the SDSL system under test. Maximum observable power levels of up to -40 dBm can occur on telephone lines in the distant vicinity of broadcast AM transmitters. The noise is typically dominated by the closest 10 or so transmitters to the victim wire-pair.

Several noise models are specified in this subclause. The average minimum power of each carrier frequency is specified in table 10.4 for each model, but this values are for further study.

Table 10.4: Average minimum RFI noise power versus frequency

frequency	99	207	333	387	531	603	711	801	909	981	kHz
power	-70	-40	-60	-60	-40	-50	-40	-50	-60	-60	dBm

10.5.3.6 Amateur RF noise generator [G6]

This noise type is left for further study.

10.5.3.7 Impulse noise generator [G7]

A test with this noise generator is required to prove the burst noise immunity of the SDSL transceiver. This immunity shall be demonstrated on short and long loops and noise to model cross-talk and RFI.

10.5.4 Profiles of the individual impairment generators

Crosstalk noise represents all impairment that originates from systems connected to adjacent wire pairs that are bundled in the same cable. Their wires are coupled to the wires of the xDSL system under test, causing this spectrum of crosstalk noise to vary with the electrical length of the testloop.

To simplify matters, the definition of crosstalk noise has been broken down into smaller, more easily specified components. The two generators G1 and G2 represent the ‘equivalent disturbance’. Their noise level originate from a mixture of many disturbers in a real scenario, as if all disturbers are colocated at the ends of the testloops.

This equivalent disturbance, filtered by the NEXT and FEXT coupling functions, will represent the crosstalk noise that is to be injected in the test setup. This approach has isolated their definition from the NEXT and FEXT coupling functions of the cable.

For SDSL testing, several models for crosstalk noise have been defined. The noise generated by these two equivalent disturbers is specified in this section in the frequency domain as well as in the time domain.

The frequency domain characteristics of each generator G1 and G2 is defined by a spectral profile, so each noise model has its own pair of spectral profiles:

- the profiles X.LT.# in this section describe the total equivalent disturbance of a technology mix that is virtually co-located at the LT end of the testloop. This noise is represented by equivalent disturbance generator G1, when stressing upstream signals, and by equivalent disturbance generator G2 when stressing downstream signals;

- the profiles X.NT.# in this section describe the total equivalent disturbance of a technology mix that is virtually co-located at the NT end of the testloop. This noise is represented by equivalent disturbance generator G2, when stressing upstream signals, and by equivalent disturbance generator G1 when stressing downstream signals.

Mark that the PSD levels of equivalent disturbance generator G1 and G2 are interchanged when changing upstream testing into downstream testing.

10.5.4.1 Frequency domain profiles for SDSL

This subclause specifies the PSD profiles X.LT.# and X.NT.# that apply for the equivalent disturbers G1 and G2 when testing SDSL systems. In this nomenclature is "#" used as a placeholder for noise model "A", "B","C", and "D".

Four noise models have been defined for SDSL:

- **type "A" models** are intended to represent a high penetration scenario where the SDSL system under test is placed in a distribution cable (up to hundreds of wire pairs) that is filled with many other (potentially incompatible) transmission systems;

- **type "B" models** are intended to represent a medium penetration scenario where the SDSL system under test is placed in a distribution cable (up to tens of wire pairs) that is filled with many other (potentially incompatible) transmission systems;

- **type "C" models** are intended to represent a legacy scenario that accounts for systems such as ISDN-PRI (HDB3), in addition to the medium penetration scenario of model "B";

- **type "D" models** are intended as reference scenario to demonstrate the difference between a cable filled with SDSL only, or filled with a mixture of SDSL techniques.

The PSD profiles for each noise model are build up by a weighed sum of two individually defined profiles: self and alien crosstalk profiles.

- X.LT.# = (XS.LT.# ♦ XA.LT.#);
- X.NT.# = (XS.NT.# ♦ XA.NT.#).

The symbols in this expression, refer to the following:

- Symbol "#" is used as a placeholder for noise model "A", "B", "C" or "D".
- Symbol "XS.LT.#" and "XS.NT.#" refers to the self crosstalk profiles, as defined in subclause 10.9.4.1.
- Symbol "XA.LT.#" and "XA.NT.#" refers to the alien crosstalk profiles, as defined in subclause 10.5.4.2.
- Symbol "♦" refers to the FSAN crosstalk sum of two PSD's. This FSAN crosstalk sum is defined as PX = (PXSKn + PXAKn)1/Kn, where P denotes the PSD’s in W/Hz, and Kn = 1/0,6.

These profiles shall be met for all frequencies between 1 kHz to 1 MHz.

10.5.4.1.1 Self crosstalk profiles

The noise profiles XS.LT.# and XS.NT.#, representing the equivalent disturbance of self crosstalk, are implementation specific of the SDSL system under test. Transceiver manufacturers are left to determine these levels. For compliance with the requirements of this technical specification, the transceiver manufacturer shall determine the signal spectrum of the SDSL system under test, as it can be observed at the Tx port of the test set-up as described in subclause 10.2.1. The measurement bandwidth for PSD shall be 1 kHz or less.

For testing SDSL, four noise models for self crosstalk have been defined. The LT- and NT-profiles are specified in table 10.4a.

In this nomenclature is "#" a placeholder for model "A", "B","C" or "D". "SDSL.dn" is the signal spectrum that SDSL transmits in downstream direction, and "SDSL.up" in upstream direction.

Table 10.4a: Definition of the self crosstalk for SDSL testing

	Model A (XS.#.A)	**Model B (XS.#.B)**	**Model C (XS.#.C)**	**Model D (XS.#.D)**
XS.LT.#:	“SDSL.dn" + 11,7 dB	“SDSL.dn" + 7,1 dB	“SDSL.dn" + 7,1 dB	“SDSL.dn" + 10,1 dB
XS.NT.#:	“SDSL.up" + 11,7 dB	“SDSL.up" + 7,1 dB	“SDSL.up" + 7,1 dB	“SDSL.up" + 10,1 dB
NOTE: The different noise models use different Gain factors.				

10.5.4.1.2 Alien crosstalk profiles

The noise profiles XA.LT.# and XA.NT.#, representing the equivalent disturbance of alien crosstalk, are implementation specific of the SDSL system under test. For testing SDSL, four noise models for alien crosstalk have been defined, The LT-profiles are specified in table 5 and the NT-profiles in table 6. Each PSD profile originates from a mix of disturbers, as described in annex B. The alien noise in model D is made inactive, to achieve one pure self crosstalk scenario.

Table 10.5: Break frequencies of the "XA.LT.#" PSD profiles that specify the equivalent disturbance spectra of alien disturbers

XA.LT.A [Hz]	*135 Ω* [dBm/Hz]	XA.LT.B [Hz]	*135 Ω* [dBm/Hz]	XA.LT.C [Hz]	*135 Ω* [dBm/Hz]	XA.LT.D [Hz]	*135 Ω* [dBm/Hz]
1	-20,0	1	-25,7	1	-25,7		
15 k	-20,0	15 k	-25,7	15 k	-25,7		
30 k	-21,5	30 k	-27,4	30 k	-27,4	*ALL*	*ZERO*
67 k	-27,0	45 k	-30,3	45 k	-30,3		
125 k	-27,0	70 k	-36,3	70 k	-36,3		
138 k	-25,7	127 k	-36,3	127 k	-36,3		
400 k	-26,1	138 k	-32,1	138 k	-32,1		
1 104 k	-26,1	400 k	-32,5	400 k	-32,5		
2.5 M	-66,2	550 k	-32,5	550 k	-32,5		
4.55 M	-96,5	610 k	-34,8	610 k	-34,8		
30 M	-96,5	700 k	-35,4	700 k	-35,3		
		1 104 k	-35,4	1 104 k	-35,3		
		4,55 M	-103,0	1,85 M	-58,5		
		30 M	-103,0	22,4 M	-103,0		
				30 M	-103,0		

NOTE: The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale. The levels are defined with into a 135 Ω resistive load.

Table 10.6: Break frequencies of the "XA.NT.#" PSD profiles that specify the equivalent disturbance spectra of alien disturbers

XA.NT.A [Hz]	*135 Ω* [dBm/Hz]	XA.NT.B [Hz]	*135 Ω* [dBm/Hz]	XA.NT.C [Hz]	*135 Ω* [dBm/Hz]	XA.NT.D [Hz]	*135 Ω* [dBm/Hz]
1	-20,0	1	-25,7	1	-25,7		
15 k	-20,0	15 k	-25,7	15 k	-25,7		
60 k	-25,2	30 k	-26,8	30 k	-26,8	*ALL*	*ZERO*
276 k	-25,8	67 k	-31,2	67 k	-31,2		
500 k	-51,9	142 k	-31,2	142 k	-31,2		
570 k	-69,5	156 k	-32,7	156 k	-32,7		
600 k	-69,9	276 k	-33,2	276 k	-33,2		
650 k	-62,4	400 k	-46,0	335 k	-42,0		
763 k	-62,4	500 k	-57,9	450 k	-47,9		
1.0 M	-71,5	570 k	-75,7	750 k	-45,4		
2.75 M	-96,5	600 k	-76,0	1 040 k	-45,5		
30 M	-96,5	650 k	-68,3	2,46 M	-63,6		
		763 k	-68,3	23,44 M	-103,0		
		1,0 M	-77,5	30 M	-103,0		
		2,8 M	-103,0				
		30 M	-103,0				

NOTE: The PSD profiles are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale. The levels are defined with into a 135 Ω.

10.5.4.2 Time domain profiles of generator G1-G4

The noise, as specified in the frequency domain in subclauses 10.4.3.1 to 10.4.3.7, shall be random in nature and near Gaussian distributed. This means that the amplitude distribution function of the combined impairment noise injected at the adding element shall lie between the two boundaries as illustrated in figure 10.6, where the non-shaded area is the allowed region. The boundaries of the mask are specified in table 10.8.

The amplitude distribution function F(a) of noise u(t) is the fraction of the time that the absolute value of u(t) exceeds the value "a". From this definition, it can be concluded that F(0) = 1 and that F(a) monotonically decreases up to the point where "a" equals the peak value of the signal. From there on, F(a) vanishes:

$$F(a) = 0 \text{, for } a \geq \left|u_{peak}\right| .$$

The boundaries on the amplitude distribution ensure that the noise is characterized by peak values that are occasionally significantly higher than the rms-value of that noise (up to 5 times the rms-value).

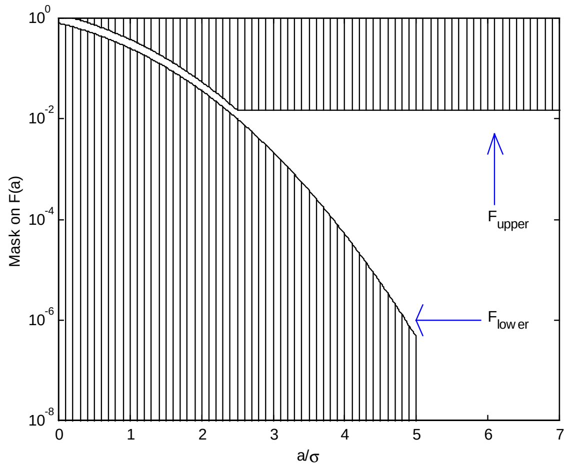


Figure 10.6: Mask for the amplitude distribution function

Table 10.7: Upper and lower boundaries of the amplitude distribution function of the noise

Boundary (σ = rms value of noise)	interval
$F_{lower}(a) = (1 - \varepsilon) \cdot \{1 - erf((a/\sigma)/\sqrt{2})\}$ $F_{lower}(a) = 0$	$0 \leq a/\sigma < CF$ $CF \leq a/\sigma < \infty$
$F_{upper}(a) = (1 + \varepsilon) \cdot \{1 - erf((a/\sigma)/\sqrt{2})\}$ $F_{upper}(a) = (1 + \varepsilon) \cdot \{1 - erf(A/\sqrt{2})\}$	$0 \leq a/\sigma < A$ $A \leq a/\sigma < \infty$

parameter	value
crest factor Gaussian gap	CF = 5 ε = 0,1 A = CF/2 = 2,5

The meaning of the parameters in table 10.7 is as follows:

- CF denotes the minimum crest factor of the noise, that characterizes the ratio between the absolute peak value and rms value ($CF = |u_{peak}| / u_{rms}$);
- ε denotes the Gaussian gap that indicates how "close" near Gaussian noise approximates true Gaussian noise;
- A denotes the point beyond which the upper limit is alleviated to allow the use of noise signals of practible repetition length.

10.6 Measurement of noise margin

At start-up, the level and shape of crosstalk noise or impulse noise are adjusted, while their level is probed at port Rx to meet the impairment level specification in subclause 10.4. This relative level is referred to as 0 dB. The transceiver link is subsequently activated, and the bit error ratio (BER) of the link is monitored.

10.6.1 Measurement of crosstalk noise margin

For measuring the crosstalk margin, the crosstalk noise level of the impairment generator as defined in Tables 8 or 9, shall be increased by adjusting the gain of amplifier A1 in figure 10.4, equally over the full frequency band of the SDSL system under test, until the bit error ratio is higher than 10^{-7}. This BER will be achieved at an increase of noise of x dB, with a small uncertainty of Δx dB. This value **x** is defined as the crosstalk noise margin with respect to a standard noise model.

The noise margins shall be measured for upstream as well as downstream transmission under testloops #1, #2, #3 and #4.

10.6.2 Measurement of impulse noise margin

For further study.

10.7 Micro interruptions

A micro interruption is a temporary line interruption due to external mechanical action on the copper wires constituting the transmission path, for example, at a cable splice. Splices can be hand-made wire-to-wire junctions, and during cable life oxidation phenomena and mechanical vibrations can induce micro interruptions at these critical points.

The effect of a micro interruption on the transmission system can be a failure of the digital transmission link, together with a failure of the power feeding (if provided) for the duration of the micro interruption.

The objective is that in the presence of a micro interruption of specified maximum length the SDSL transceiver should not reset, and the system should automatically reactivate.

The transceiver shall not be reset by a microinterruption event with a duration t = 10 ms which shall occur at an event frequency of 0,2 Hz.

11 Power feeding

11.1 General

This clause deals with power feeding of the NTU, regenerators (if required) and the provision of power to the application interface for narrowband services under restricted conditions (life line circuit).

The requirements given in this clause imply compliance to EN 60950 [5].

11.2 Power feeding of the NTU

The NTU 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 NTU shall draw between 200 µA and up to a maximum of 3 mA as wetting current from the remote feeding circuit when the NTU is being powered locally. When the local power fails the maximumcurrent drawn by the NTU from the remote feeding circuit shall be limited to the value specified in EN 60950 [5].

11.3 Power feeding of the interface for narrowband services

When simultaneous telephone service is provided by the NTU, feeding of restricted mode power for life line service has to be provided for at least one telephone set in case of local power fail. The requirements for ISDN-BA are described in ETS 300 012-1 [16] and for analogue access in ETS 300 001 [4] and TBR 21 [13].

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.

11.4 Feeding power from the LTU

The feeding power shall be limited to the values specified in EN 60950 [5] to meet the requirements for TNV.

NOTE: This means that the sum of the DC- and AC-voltage at the NTU should not exceed 120 V.
The safety standards may for extraordinary cases with long lines or regenerators allow higher power to be supplied from the LTU. 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.

11.5 Power available at the NTU

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

When remote power feeding is provided by the network the NTU and the side of the REG directed towards the LTU shall enter a high impedance state within 2 s after interruption of the remote current fed towards the NTU or the REG 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.

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

12 Environmental requirements

12.1 Climatic conditions

Climatograms applicable to the operation of SDSL equipment can be found in ETS 300 019 [6]. The choice of classes is under national responsibility.

12.2 Safety

Safety requirements are mentioned in clause 11 "Power feeding".

12.3 Overvoltage protection

No overvoltage protection requirements are specified under the present document.

NOTE: Dependent on the equipment NTU, LTU or REG the ITU-T Recommendations and CCITT Recommendations K.21 [11], K.20 [10] or K.17 [9] should be applied.

12.4 Electromagnetic compatibility

The EMC requirements are defined according to the equipment type and as described in EN 300 386 [7]

NOTE: Additional EMC requirements may be imposed under EMC Directive (89/336/EEC) [17].

Annex A (informative): Typical characteristics of cables

These cable characteristics are adopted from TS 101 135 [2]. The description by means of full two port models is currently under study.

Table A.1: Parameters of PE 04

Frequency	0 Hz	10 kHz	20 kHz	40 kHz	100 kHz	150 kHz	200 kHz	400 kHz	500 kHz
R' (Ω/km)	268	268	269	271	282	295	312	390	425
L' (µH/km)	680	678	675	669	650	642	635	619	608
C' (nF/km)	45,5	45,5	45,5	45,5	45,5	45,5	45,5	45,5	45,5

Table A.2: Parameters of PE 05

Frequency	0 Hz	10 kHz	20 kHz	40 kHz	100 kHz	150 kHz	200 kHz	400 kHz	500 kHz
R' (Ω/km)	172	172	173	175	190	207	227	302	334
L' (µH/km)	680	678	675	667	646	637	629	603	592
C' (nF/km)	25	25	25	25	25	25	25	25	25

Table A.3: Parameters of PE 06

Frequency	0 Hz	10 kHz	20 kHz	40 kHz	100 kHz	150 kHz	200 kHz	400 kHz	500 kHz
R' (Ω/km)	119	120	121	125	146	167	189	260	288
L' (µH/km)	700	695	693	680	655	641	633	601	590
C' (nF/km)	56	56	56	56	56	56	56	56	56

Table A.4: Parameters of PE 08

Frequency	0 Hz	10 kHz	20 kHz	40 kHz	100 kHz	150 kHz	200 kHz	400 kHz	500 kHz
R' (Ω/km)	67	70	72,5	75,0	91,7	105	117	159	177,5
L' (µH/km)	700	700	687	665	628	609	595	568	543
C' (nF/km)	37,8	37,8	37,8	37,8	37,8	37,8	37,8	37,8	37,8

Table A.5: Parameters of PVC 032

Frequency	0 Hz	10 kHz	20 kHz	40 kHz	100 kHz	150 kHz	200 kHz	400 kHz	500 kHz
R' (Ω/km)	419	419	419	419	427	453	493	679	750
L' (µH/km)	650	650	650	650	647	635	621	577	560
C' (nF/km)	120	120	120	120	120	120	120	120	120

Table A.6: Parameters of PVC 04

Frequency	0 Hz	10 kHz	20 kHz	40 kHz	100 kHz	150 kHz	200 kHz	400 kHz	500 kHz
R' (Ω/km)	268	268	268	268	281	295	311	391	426
L' (µH/km)	650	650	650	650	635	627	619	592	579
C' (nF/km)	120	120	120	120	120	120	120	120	120

Table A.7: Parameters of PVC 063

Frequency	0 Hz	10 kHz	20 kHz	40 kHz	100 kHz	150 kHz	200 kHz	400 kHz	500 kHz
R' (Ω/km)	108	108	108	111	141	173	207	319	361
L' (µH/km)	635	635	635	630	604	584	560	492	469
C' (nF/km)	120	120	120	120	120	120	120	120	120

History

Document history		
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